DOCUMENT RESUME

ED 223 903 CE 034 543

TITLE	Construction Mechanic Part II, 8-6. Military Curriculum Materials for Vocational and Technical Education.
INSTITUTION	Naval Construction Training Center, Port Hueneme, Calif.; Ohio State Univ., Columbus. National Center for Research in Vocational Education.
SPONS AGENCY	Office of Education (DHEW), Washington, D.C.
PUB DATE	78
NOTE	936p.; for related documents, see CE 034 542-545.
PUB TYPE	Guides - Classroom Use - Materials (For Learner) (051) -- Guides - Classroom Use - Guides (For Teachers) (052)
EDRS PRICE	MF06/PC38 Plus Postage.
DESCRIPTORS	Audiovisual Aids; *Auto Mechanics; Behavioral Objectives; Course Content; *Diesel Engines; Educational Resources; *Engines; Equipment; Learning Activities; Lesson Plans; *Mechanics (Process); *Motor Vehicles; Postsecondary Education; *Power Technology; Secondary Education; Technical Education; Units of Study; Vocational Education
IDENTIFIERS	Military Curriculum Project

ABSTRACT

This course, adapted from military curriculum materials for use in vocational and technical education, is the second of a two-course series that teaches students to maintain and repair automotive and construction equipment using either gasoline or diesel engines. It covers basic chassis and power train troubleshooting, diagnosis, and adjustment procedures. The course contains two phases covering 117 hours of instruction. Phase 3 on automotive chassis and power contains one unit with three lessons covering 75 hours of instruction; phase 4 on heavy equipment chassis and power contains one unit on crawler tractor-power train maintenance containing three lessons covering 42 hours of instruction. The course contains both student and teacher materials. Printed instructor materials include a curriculum outline for the course and instructor guides for each phase. The curriculum outline includes an introduction to the course; outline of instruction; outline of training objectives; lists of texts, references, tools, equipment; materials, training aids and devices, and training aids equipment; and a master schedule. The instructor guides have the lesson plans for each unit. Student materials include 11 job sheets, 11 information sheets, 1 work sheet, and 3 problem sheets. Appropriate text materials from three Navy manuals are provided. (KC)

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MILITARY CURRICULUM MATERIALS

The military-developed curriculum materials in this course package were selected by the National Center for Research in Vocational Education Military Curriculum Project for dissemination to the six regional Curriculum Coordination Centers and other instructional materials agencies. The purpose of disseminating these courses was to make curriculum materials developed by the military more accessible to vocational educators in the civilian setting.

The course materials were acquired, evaluated by project staff and practitioners in the field, and prepared for dissemination. Materials which were specific to the military were deleted, copyrighted materials were either omitted or approval for their use was obtained. These course packages contain curriculum resource materials which can be adapted to support vocational instruction and curriculum development.

The National Center Mission Statement

The National Center for Research in Vocational Education's mission is to increase the ability of diverse agencies, institutions, and organizations to solve educational problems relating to individual career planning, preparation, and progression. The National Center fulfills its mission by:

- Generating knowledge through research
- Developing educational programs and products
- Evaluating individual program needs and outcomes
- Installing educational programs and products
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FOR FURTHER INFORMATION ABOUT
Military Curriculum Materials
WRITE OR CALL
Program Information Office
The National Center for Research in Vocational Education
The Ohio State University
1960 Kenny Road, Columbus, Ohio 43210
Telephone: 614/486-3655 or Toll Free 800/848-4815 within the continental U.S. (except Ohio)

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Military Curriculum Materials for Vocational and Technical Education

Information and Field Services Division

The National Center for Research in Vocational Education

Military Curriculum Materials Dissemination Is . . .

an activity to increase the accessibility of military-developed curriculum materials to vocational and technical educators.

This project, funded by the U.S. Office of Education, includes the identification and acquisition of curriculum materials in print form from the Coast Guard, Air Force, Army, Marine Corps and Navy.

Access to military curriculum materials is provided through a "Joint Memorandum of Understanding" between the U.S. Office of Education and the Department of Defense.

The acquired materials are reviewed by staff and subject matter specialists, and courses deemed applicable to vocational and technical education are selected for dissemination.

The National Center for Research in Vocational Education is the U.S. Office of Education's designated representative to acquire the materials and conduct the project activities.

Project Staff:

Wesley E. Budke, Ph.D., Director
National Center Clearinghouse

Shirley A. Chase, Ph.D.
Project Director

What Materials Are Available?

One hundred twenty courses on microfiche (thirteen in paper form) and descriptions of each have been provided to the vocational Curriculum Coordination Centers and other instructional materials agencies for dissemination.

Course materials include programmed instruction, curriculum outlines, instructor guides, student workbooks and technical manuals.

The 120 courses represent the following sixteen vocational subject areas:

- Agriculture
- Aviation
- Building & Construction Trades
- Clerical Occupations
- Communications
- Drafting
- Electronics
- Engine Mechanics
- Food Service
- Health
- Heating & Air Conditioning
- Machine Shop
- Management & Supervision
- Meteorology & Navigation
- Photography
- Public Service

The number of courses and the subject areas represented will expand as additional materials with application to vocational and technical education are identified and selected for dissemination.

How Can These Materials Be Obtained?

Contact the Curriculum Coordination Center in your region for information on obtaining materials (e.g., availability and cost). They will respond to your request directly or refer you to an instructional materials agency closer to you.

CURRICULUM COORDINATION CENTERS

EAST CENTRAL
Rebecca S. Douglass
Director
100 North First Street
Springfield, IL 62777
217/782-0759

MIDWEST
Robert Patton
Director
1515 West Sixth Ave.
Stillwater, OK 74704
405/377-2000

NORTHEAST
Joseph F. Kelly, Ph.D.
Director
225 West State Street
Trenton, NJ 08625
609/292-6562

NORTHWEST
William Daniels
Director
Building 17
Airdustrial Park
Olympia, WA 98504
206/753-0879

SOUTHEAST
James F. Shill, Ph.D.
Director
Mississippi State University
Drawer DX
Mississippi State, MS 39762
601/325-2510

WESTERN
Lawrence F. H. Zane, Ph.D.
Director
1776 University Ave.
Honolulu, HI 96822
808/948-7834

CONSTRUCTION MECHANIC, CLASS A, PART II

Classroom Course

Developed by:
United States Navy

Development and Review Dates:
May 1975

D.O.T. No.:
620.281

Occupational Area:
Engine Mechanics

Target Audiences:
Grades 11-adult

Print Pages:
684

Cost:

Availability:
Military Curriculum Project, The Center for Vocational Education, 1960 Kenny Rd., Columbus, OH 43210

Contents:	Type of Materials:						Instructional Design:				Type of Instruction:	
	Lesson Plans:	Programmed Text:	Student Workbook:	Handouts:	Text Materials:	Audio-Visuals:	Performance Objectives:	Tests:	Review Exercises:	Additional Materials Required:	Group Instruction:	Individualized:
Phase 3												
Automotive Chassis and Power Trains												
Unit 1 – Automotive Chassis and Power Trains	●			●	●		●	●		*	●	●
Phase 4												
Heavy Equipment Chassis and Power Train												
Unit 1 – Crawler Tractor Power Train Maintenance	●			●	●		●	●		*	●	●

* Materials are recommended but not provided.

Expires July 1, 1978

Course Description:

This course is the second of a two-course series which teaches students to maintain and repair automotive and construction equipment using either gasoline or diesel engines. It covers basic chassis and power train troubleshooting, diagnosis, and adjuctment procedures. Students should complete **Construction Mechanic, Class A, Part I**, before beginning this course. This course contains two phases covering 117 hours of instruction.

Phase 3 – *Automotive Chassis and Power Trains* contains one unit with three lessons covering 75 hours of instruction. A fourth lesson is deleted because it covers the repair of a peice of military equipment. The units, lessons, and hours follow:

Unit 1 – **Automotive Chassis and Power Trains**

3.1.1 Suspension Systems Service (5 hours classroom, 8 hours practical)
3.1.2 Automotive Power Trains Service (6 hours classroom, 29 hours practical)
3.1.3 Brake System Service (7 hours classroom, 20 hours practical)

Phase 4 – *Heavy Equipment Chassis and Power Train* contains one unit on crawler tractor power train maintenance containing three lessons covering 42 hours of instruction.

Unit 1 – **Crawler Tractor Power Train Maintenance**

4.1.1 Oxy-Mapp Gas Cutting (2 hours classroom, 4 hours practical)
4.1.2 Construction Equipment Power Trains (12 hours classroom, 20 hours practical)
4.1.3 Adjustment of International Model 260 Cable Control Unit (2 hours classroom, 2 hours practical)

This course contains both student and teacher materials. Printed instructor materials include a curriculum outline for the course, and instructor guides for each phase. The curriculum outline includes an introduction to the course; outline of instruction; outline of training objectives; and lists of texts, references, tools, equipment; materials, training aids and devices, and training aids equipment; and a master schedule. The instructor guides have the lesson plans for each unit. Student materials include eleven job sheets, eleven information sheets, one work sheet, and three problem sheets.

The appropriate text materials from three Navy manuals are provided. An additional 27 recommended commercial texts and technical manuals are not provided. Seven additional military and commercial references are suggested. The audiovisuals recommended for the two course-series, but not provided include twenty-three military films, fourteen commercial films, twenty-two slide films, thirty-seven slides, two transparencies, and eight charts. The instructor may be able to substitute similar materials which are on-hand for these additional items.

CONSTRUCTION MECHANIC, CLASS A, PART II

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Construction Mechanic

Chapter 4 - Fuels and Lubricants Page 565

Chapter 8 - The Diesel Engine Page 576

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Steelworker 3 & 2

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CNTT-A41

CURRICULUM OUTLINE
FOR
CONSTRUCTION MECHANIC, CLASS A

A-610-0022

Prepared By
U.S. NAVAL CONSTRUCTION TRAINING CENTER
Port Hueneme CA. 93043

MAY 1975

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Encl. ([illegible])

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CO, USMC ENGR SCOL, CAMP LEJUNE, NC	2
TOTAL	22

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TITLE PAGE

TITLE: Construction Mechanic "A"

COURSE NO.: A-610-0022

COURSE LENGTH: 13 Weeks, 05 hours

TAUGHT AT: Naval Construction Training Center, Port Hueneme, Ca. 93043
Naval Construction Training Center, Gulfport, Ms. 39501

CLASS CAPACITY: Normal: 20
Maximum: 24
Minimum: 16

INSTRUCTOR REQUIREMENTS PER CLASS: Class: 24/1
Pract: 6/1
Field: 24/1

COURSE CURRICULUM MODEL MANAGER: Naval Construction Training Center,
Port Hueneme, California 93043

CURRICULUM CONTROL: Chief of Naval Technical Training

QUOTA MANAGEMENT AUTHORITY: Chief of Naval Technical Training

QUOTA CONTROL: BUPERS

APPROVAL/IMPLEMENTATION DATE: Chief of Naval Technical Training ltr
N3351:stb, 1500, Ser 33/445 of 20 May 1975

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INTRODUCTION

1. This curriculum was developed by Naval Construction Training Center, Port Hueneme, California 93043, as Course Model Manager, and is effective upon final approval of the Chief of Naval Technical Training.

2. Commands are invited to submit explicit comments on the content of this curriculum to the Commanding Officer, Naval Construction Training Center, Port Hueneme, California 93043, with copies to the Chief of Naval Technical Training, Naval Air Station Memphis (75), Millington, Tennessee 38054 and the Commanding Officer, Naval Construction Training Center, Gulfport, Mississippi 39501.

3. Training Notes

This course has been developed and designed in accordance with the principles of systems engineering. In order to insure that the objectives of each unit are met, it is expected that the instructor will teach the topics as outlined in accordance with the referenced publications. Deviation is allowed only to exceed or supplement the required instruction. Lesson outlines in the instructor guides are to be used as a guide in the presentation of the lesson. While it is compulsory that all objectives of each training period be met, it is recognized that the specified times established for each lesson may vary with the achievement level of each group of students, the number of students per cycle, the instructor-to-student ratio, and the availability of facilities. It is the responsibility of the school to provide for the efficient implementation and administration of this publication and to ensure that each of the learning activities outlined herein is taught in a manner which provided a maximum gain in knowledge and skill for each student.

4. Training Methods

a. The traditional methods of conference, demonstration and practical exercise are used during this course of instruction. In keeping with changes which potentially will benefit the instruction, other methods are also included:

(1) Information presentations: These are designed primarily to make information available in a group setting, have no objectives, and are not instructional. No tests are given on information presentations.

(2) Self-study text materials: These individualized materials do have objectives and are instructional and will be tested at the end of each section of the student workbook.

(3) Group audio-visual presentations: These presentations can be either informational or instructional.

(4) Progress evaluation test: Tests that are inserted at critical points to determine student's capabilities to perform objectives.

(5) Group interactive lecture: Group participates by responding to situations presented verbally by the instructor or in the workbooks provided to the students.

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b. Schools will emphasize the importance of performance-orientated training wherein learning-by-doing rather than listening and watching is practiced. Time devoted to the traditional methods of instruction will be limited in favor of the more recent methods outlined in paragraph 4a. Although some of the methods depend to a great extent on availability of audio-visual aids, there are other alternatives that can be developed at the training center using existing material.

c. The student learns best in a job-relevant environment. Time devoted to lectures, conferences and demonstrations should be held to the minimum required for explaining the objectives, course organization, safety precautions, and other introductory-type subjects pertinent to the course.

5. Testing Concepts:

Criterion testing (tests designed to measure performance of specific objectives) will be used to measure student performance. Each student will be tested on each learning objective to the level of proficiency stated in the objective. A series of performance tests for each scheduled evaluation is provided at the end of each unit. Each test requirement or problem is closely related to specific training objectives and performance standards. Standards of proficiency are stated explicitly in performance tests. Proficiency testing is conducted using the pass/fail, go/no-go technique. Student performance during the formative tests will provide indicators as to need for additional training on an individual or group basis. Performance on the pass/fail tests conducted after each phase of the course provides the basis for determining whether or not a student will be graduated. Unit tests will be used in determining class standing and honor graduates.

6. How to Use Instructor Guides.

Instructor Guides are provided for each topic and include supporting instructional materials and aids identified by the topic number and preceded by a letter code designation. The letter code key is as follows:

AS - Assignment Sheet
JS - Job Sheet
IS - Information Sheet
CN - Class Notes
TR - Transparency
OS - Operation Sheet
T - Test
FT - Final Test
DS - Diagram Sheet
PS - Problem Sheet
PE - Performance Evaluation
WB - Workbook
G - Definition of Item in General

A complete list of all supporting materials and aids is documented with full descriptive titles in ANNEX I thru VII.

The instructor guides are intended to be used as master lesson plans subject to personalization by the individual instructor. In all cases, it is expected that the instructor will study the references in preparation for annotating the guide. It is also expected that each instructor will develop an appropriate introduction for each topic that will (1) create interest, (2) show the value of the topic to the student, (3) relate the topic to previous and future topics in the course, and (4) communicate the learning objectives to the student. Well prepared introductions will then provide the important motivational conditioning to establish readiness and effect for learning appropriate to each topic.

The first page of each instructor guide contains the following functional information:

1. Topic of Lesson
2. Time in Periods
3. References
4. Instructional Aids
5. Instructional Materials
6. Objectives (Terminal and Enabling)
7. Topic Criterion Test (as applicable)
8. Homework Assignment (when applicable)

The pages following page 1 of each instructor guide provide in a three-column format the teaching/learning procedures for conducting the lesson. The left-hand column includes the outline of instructional content required by the objectives; the center column includes recommended instructor activities or methodology; the right-hand column contains recommended student learning activities.

a. While the methodology and student learning activities documented in each instructor guide have been tested and proven to be effective for the lead school, those schools implementing this curriculum are encouraged to exercise creativity in designing learning exercises and conceiving methods and techniques to meet course objectives.

b. Instructors and supervisors of instruction should constantly evaluate the program and seek new and more effective methods, content, and procedures to improve their instruction. When changes in this curriculum become necessary because of new developments or because of needs that become evident through experience gained in using the curriculum, the school command is encouraged to take appropriate action. The types of changes and the conditions under which they will be made are as follows:

(1) Type A changes and those of course length; change in title of the course; or addition, deletion or alternation of blocks of subject matter to such an extent that the objectives of courses are changed, or that logistics, personnel allocations, funds and the like become involved. For Type A changes, the CNTECHTRA (Code 0162A) must participate in the planning, development and execution. Type A changes may not be made effective until approved by the Chief of Naval Technical Training.

(2) Type B changes are those within established structure of the course such as changes in instructional emphasis that are brought about by changes in topic content or time re-allocation (other than minor adjustments in time), changes in instructional procedures, and similar actions that will alter the objectives of a topic. For Type B changes, approval of the Chief of Naval Technical Training must be gained prior to implementing the changes.

(3) Type C changes include corrections of clerical errors; insertion of titles and designations of new films; publications, and equipment; minor adjustments in time allocations; additional suggestions to assist the instructor and so forth. For Type C changes, the Chief of Naval Technical Training must be notified in writing of the nature of the changes, with sufficient information on the mechanics of the changes to make possible the maintenance of an up-to-date copy of the curriculum. In order to avoid unnecessary paper work, Type C changes may be accumulated and reported only when the quantity or occasion warrants.

c. Formative Test: During the classroom phase of the instruction at specific checkpoints identified by the instructor, informal written tests will be administered to demonstrate mastery of specific subjects. These tests are designed to reinforce learning. Tests are administered at the end of each unit of instruction. Formal tests may vary from 10 - 25 multiple-choice questions and will have bearing to influence class standing and to determine honor graduates.

7. Peer Instruction.

It is envisioned that those students who learn faster or who have previously developed a particular skill can be used (after demonstrating proficiency in the subject) as peer instructors to assist slow learners. This technique enhances motivation and early subject mastery while minimizing requirements. Care should be taken not to pair students with widely disparate learning abilities. i.e., a student who has finished step 10 should not be paired with a student who is finishing step 2. He should help a student who is finishing step 8 or 9 and a student who has finished step 3 or 4 should help the student at step 2. In this way, there is a better chance that there will be no resentment of the peer instructor and he will also receive reinforcement from the instruction, having just completed the task himself.

OUTLINE OF INSTRUCTION

PHASE 1

GASOLINE ENGINES

TOPIC	UNIT 1	CLASS	PRACT	TOTAL	PAGE
	Introduction				
1.1.0	NAVCONSTRACEN Indoctrination	4	0	4	5
1.1.1	Registration and Orientation	1	0	1	5
1.1.2	Study Techniques	1	0	1	5
1.1.3	Safety Policies	1	0	1	5
		7	0	7	
	UNIT 2				
	Gasoline Engine Repair and Adjustment				
1.2.1	Internal Combustion Engine Principles	15	5	20	6
1.2.2	Electrical System Principles	18	4	22	6
1.2.3	Gasoline Engine Disassembly	4	7	11	6
1.2.4	Inspection and Measuring of Engine Components	5	10	15	6
1.2.5	Gasoline Engine Assembly	2	8	10	6
1.2.6	Gasoline Engine Trouble, Diagnosis and Adjustment	10	15	25	7
		54	49	103	

PHASE 2

DIESEL ENGINES

	UNIT 1				
	Caterpillar Diesel Engine Operation and Maintenance				
2.1.1	Caterpillar Diesel Engine Operation	5	2	7	7
2.1.2	Caterpillar Diesel Engine Maintenance	11	13	24	7
		16	15	31	
	UNIT 2				
	International Diesel Engine Operation and Maintenance				
2.2.1	International Diesel Engine Operation	2	2	4	8
2.2.2	International Diesel Engine Maintenance	11	18	29	8
		13	20	33	

COURSE DATA PAGE

COURSE MISSION: To provide basic technical knowledge and skills in performing maintenance and repair of automotive and construction equipment in preparation for immediate usefulness to the construction forces as Construction Mechanics.

PREREQUISITES: Selected CN, CA, SN, FN and candidates should be volunteers for Group VIII ratings.

OBLIGATED SERVICE: See TRANSMAN, NAVPERS 15909

SECURITY CLEARANCE REQUIRED: None.

NEC GAINED: None

PHYSICAL REQUIREMENTS: None

PREREQUISITE TRAINING AND/OR BASIC BATTERY TEST SCORES REQUIRED:

USN - GCT + Mech + Shop Pract = 150
USNR - GCT + Mech = 100

GRADING WEIGHT FACTORS: Performance of tasks throughout the course will be graded on a go/no go basis with written tests given at the end of each topic.

Final result to be class ranking specifically designed to enable the Commanding Officer to comply with Bureau of Naval Personnel directives relative to class standings.

TOPIC	UNIT 2	CLASS	PRACT	TOTAL	PAGE
	Graduation				
4.2.1	Graduation	$\frac{0}{0}$	$\frac{1}{1}$	$\frac{1}{1}$	

* Total Classroom Periods - 163
* Total Practical Periods - 232
Total Periods for Course - 395

Total Weeks for Course - 13 Weeks and 5 Hours

** Total GMT Periods - 66
*** Total Admin Time - 9 hours

* All periods represent 60 minutes of actual instruction

** GMT - General Military Training required by OPNAV Instructions 1500.22 Series, 6330.1 Series and other current instructions to include physical training, upward, drug and alcohol abuse, etc.

*** Admin Time - Time before graduation to permit out-processing of students, i.e. shots, JAMTO, text book return, course critique, BEQ and school field day.

TOPIC	UNIT 3	CLASS	PRACT	TOTAL	PAGE
	General Motors Diesel Engine Operation and Maintenance				
2.3.1	General Motors Diesel Engine Operation	4	2	6	8
2.3.2	General Motors Diesel Engine Maintenance	10	16	26	8
		14	18	32	
	UNIT 4				
	Cummins Diesel Engine Operation and Maintenance				
2.4.1	Cummins Diesel Engine Operation	2	2	4	9
2.4.2	Cummins Diesel Engine Maintenance	8	13	21	9
		10	15	25	
	UNIT 5				
	LD465-1 Multifuel Engine Operation and Maintenance				
2.5.1	LD465-1 Multifuel Engine Operation	3	2	5	9
2.5.2	LD465-1 Multifuel Engine Maintenance	8	15	23	10
		11	17	28	

PHASE 3

AUTOMOTIVE CHASSIS AND POWER TRAIN

	UNIT 1				
	Automotive Chassis and Power Train Maintenance				
3.1.1	Suspension System Service	5	8	13	10
3.1.2	Automotive Power Train Service	6	29	35	10
3.1.3	Brake System Service	7	20	27	11
3.1.4	Servicing the M-715 1 1/4 Ton Cargo Truck	4	4	8	11
		22	61	83	

PHASE 4

HEAVY EQUIPMENT CHASSIS AND POWER TRAIN

	UNIT 1				
	Crawler Tractor Power Train Maintenance				
4.1.1	Oxy-Mapp Gas Cutting	2	4	6	11
4.1.2	Construction Equipment Power Trains	12	30	42	12
4.1.3	Adjustment of International Model 260 Cable Control Unit	2	2	4	12
		16	36	52	

Topic 1.2.1 INTERNAL COMBUSTION ENGINE PRINCIPLES Contact Hours: 20

Enabling Objectives: Upon completion of this topic each student will be able to identfiy and select with 100% accuracy all engine parts while considering principles of operation of an internal combustion engine. He will be evaluated on a continuing basis. Throughout the engine disassembly, measuring and inspection of parts and reassembly sections of CM "A" JS 1.2.3.1.

Topic 1.2.2 ELECTRICAL SYSTEM PRINCIPLES Contact Hours: 22

Enabling Objectives: Upon completion of this topic each student will be able to identify by name the following electrical system components: The ignition system, the cranking system, the charging system, the lighting system, and the accessory system and explain the operating principles of each system with 100% accuracy. Each student will be evaluated on a continuing basis throughout engine disassembly, assembly and specifically CM "A" JS 1.2.6.1, Gasoline Engine Trouble Diagnosis and Adjustment.

Topic 1.2.3 GASOLINE ENGINE DISASSEMBLY Contact Hours: 11

Enabling Objectives: Upon completion of this topic each student will be able to disassemble a six cylinder gasoline engine while working as a member of a two (2) man team, using a Ford, 240 cubic inch engine. He will use all appropriate handtools, special tools and shop equipment. The task will be accomplished while adhering to manufacturer's specifications and recommendations without deviation as specified in Job Sheet CM "A" JS 1.2.3.1, Gasoline Engine Disassembly, Inspection and Assembly.

Topic 1.2.4 INSPECTION AND MEASURING OF ENGINE PARTS Contact Hours: 15

Enabling Objectives: Upon completion of this topic each student will be able to clean, inspect and measure engine parts of a Ford 240 cubic inch gasoline engine while working as a member of a two (2) man team. He will use appropriate handtools, special tools, measuring instruments and cleaning materials. All measurements will be recorded in appropriate spaces on Job Sheet and compared to manufacturer's specifications to determine extent of wear. All procedures will conform to manufacturer's specifications without deviation as specified in Job Sheet CM "A" JS 1.2.3.1, Gasoline Engine Disassembly, Inspection and Assembly.

Topic 1.2.5 GASOLINE ENGINE ASSEMBLY Contact Hours: 10

Enabling Objectives: Upon completion of this topic each student will be able to assemble a six cylinder gasoline engine while working as a member of a two (2) man team, using a Ford, 240 cubic inch engine. He will use all appropriate handtools, special tools, shop equipment and materials. The task will be accomplished while conforming to manufacturer's specifications without deviation as specified in Job Sheet CM "A" JS 1.2.3.1, Gasoline Engine Disassmebly, Inspection and Assembly.

OUTLINE OF TRAINING OBJECTIVES

UNIT 1.1 INTRODUCTION Contact Hours: 7

Terminal Objective: Upon completion of this unit each student will have registered for the course, received course textbooks, answered questions pertaining to key points on the organization, mission, and regulations of NAVCONSTRACEN and CBC, reviewed class schedule, met his counselor, stated the standards of the school, described the benefits that can be derived from good study texhniques, listed the factors contributing to the enhancement of good study techniques, stated how to report accidents or fires and listed the safety practices that will be enforced in the school.

Topic 1.1.0 NAVCONSTRACEN INDOCTRINATION Contact Hours: 4

Enabling Objectives: Upon completion of this topic each student will be able to answer questions pertaining to key points on the organization, mission and regulations of CBC and NAVCONSTRACEN. The student will complete Response Sheet 001/911C with 100% accuracy.

Topic 1.1.1 REGISTRATION AND ORIENTATION Contact Hours: 1

Enabling Objectives: Upon completion of this topic each student will have registered for the course, received textbooks, met his class counselor, answered questions pertaining to the organization, mission and regulations of the school and stated the standards of the school without reference to written material.

Topic 1.1.2 STUDY TECHNIQUES Contact Hours: 1

Enabling Objectives: Upon completion of this topic each student will have described the benefits that may be derived from good study techniques and stated the factors contributing to the enhancement of good study techniques.

Topic 1.1.3 SAFETY Contact Hours: 1

Enabling Objectives: Upon completion of this topic each student will be able to properly report fires and accidents and list the safety practices that will be enforced in this school.

UNIT 1.2 INTERNAL COMBUSTION ENGINES Contact Hours: 103

Terminal Objective: Upon completion of this unit each student will be able to disassemble, assemble, tune and adjust a six cylinder gasoline engine using a Ford, 240 cubic inch engine. Using appropriate handtools, shop equipment and materials, he will accomplish this task in accordance with Job Sheets CM "A" JS 1.2.3.1, Gasoline Engine Disassembly, Inspection and Assembly and CM "A" JS 1.2.6.1, Gasoline Engine Diagnosis and Adjustment. Upon completion of assembly and tune up, the engine shall perform with an ignition timing of 6^{o} B.T.C., dwell of 37^{o} - 42^{o}, idle at 550 rpm, intake manifold of 18 - 21 inches, oil pressure and coolant temperature in normal operating range.

Topic 2.2.1 INTERNATIONAL DIESEL ENGINE OPERATION Contact Hours: 4

Enabling Objectives: Upon completion of this topic each student will be able to prestart check, start, operate and secure International diesel engine model 429 while working as a member of a two (2) man team. Additionally, he will monitor instruments and interpret readings. All performance will conform without error to manufacturer's recommendations as specified in the Job Sheet CM "A" JS 2.2.1.1, Maintenance of International Diesel Engines.

Topic 2.2.2 INTERNATIONAL DIESEL ENGINE MAINTENANCE Contact Hours: 29

Enabling Objectives: Upon completion of this topic each student will be able to service International diesel engine model 429, while working as a member of a two (2) man team. He will use all appropriate handtools, special tools and shop equipment. Specifically, he will service fuel injection system, scavenging system, cooling system and lubricating system. All tasks will conform to manufacturer's recommendations as stated in Job Sheet CM "A" JS 2.2.1.1, Maintenance of International Diesel Engines.

UNIT 2.3 GENERAL MOTORS DIESEL ENGINE MAINTENANCE Contact Hours: 32

Terminal Objective: Upon completion of this unit each student will be able to operate and service General Motors 71 series diesel engines while using appropriate hand tools, special tools and materials. He will operate the engine and conduct service procedures to the fuel system, cooling system, lubricating system and scavenging system with all tasks conforming without error to manufacturer's specifications and recommendations as specified in Job Sheet CM "A" JS 2.3.1.1, Maintenance of General Motors Diesel Engines.

Topic 2.3.1 GENERAL MOTORS DIESEL ENGINE OPERATION Contact Hours: 6

Enabling Objectives: Upon completion of this topic each student will be able to operate a General Motors 71 series diesel engine. He will prestart check, start, run and secure the engine, while monitoring the instruments and interpreting their readings to determine normal or abnormal function of engine systems as related to the two stroke cycle principle of operation. All tasks will be in accordance with manufacturer's specifications, without error, as outlined in the Job Sheet CM "A" JS 2.3.1.1, General Motors Operation and Maintenance.

Topic 2.3.2 GENERAL MOTORS DIESEL ENGINE MAINTENANCE Contact Hours: 26

Enabling Objectives: Upon completion of this topic each student will be able to service General Motors 71 series diesel engines while using appropriate handtools, special tools, and shop equipment. He will service the scavenging system, lubricating system, cooling system and fuel system. All tasks will conform to manufacturer's specifications without deviation, as specified in the Job Sheet CM "A" JS 2.3.1.1, Maintenance of General Motors Diesel Engines.

Topic 1.2.6 GASOLINE ENGINE TROUBLE DIAGNOSIS AND ADJUSTMENT Contact Hours: 25

Enabling Objectives: Upon completion of this topic each student will be able to test, tune and troubleshoot a six cylinder gasoline engine using a Ford, 240 cubic inch engine. He will use appropriate handtools and test equipment. All performances will conform to procedures established by Job Sheet CM "A" JS 1.2.6.1, Gasoline Engine Diagnosis and Adjustment. The engine will be tuned to meet manufacturer's specifications as to ignition timing of 6° B.T.C., dwell 37° - 42°, idle speed 550 rpm and intake manifold vacuum of 18 - 21 inches. His performance will comply with Job Sheet procedures without error.

UNIT 2.1 CATERPILLAR DIESEL ENGINE OPERATION AND MAINTENANCE Contact Hours: 31

Terminal Objective: Upon completion of this unit each student will be able to operate and service Caterpillar diesel engines, models D-342 and D-3306. He will use appropriate hand tools, special tools and shop equipment. His performance will conform to manufacturer's recommendations as outlined in the Job Sheet CM "A" JS 2.1.1.1, Maintenance of Caterpillar Diesel Engines, without error.

Topic 2.1.1 CATERPILLAR DIESEL ENGINE OPERATION Contact Hours: 7

Enabling Objectives: Upon completion of this topic each student will be able to prestart check, start, run and secure Caterpillar diesel engines, models D-342 and D-3306, while monitoring instruments and interpreting readings. All performance will conform to manufacturer's recommendations as stated in the Job Sheet CM "A" JS 2.1.1.1, Maintenance of Caterpillar Diesel Engines, without error.

Topic 2.1.2 CATERPILLAR DIESEL ENGINE MAINTENANCE Contact Hours: 24

Enabling Objectives: Upon completion of this topic each student will be able to service Caterpillar diesel engines models D-342 and D-3306 using appropriate handtools, special tools and shop equipment. Specifically he will service cranking systems, fuel systems and adjustment of engine valve systems. All tasks will meet manufacturer's specifications as specified in Job Sheet CM "A" JS 2.1.1.1, Maintenance of Caterpillar Diesel Engines, without deviation.

UNIT 2.2 INTERNATIONAL DIESEL ENGINE MAINTENANCE Contact Hours: 33

Terminal Objective: Upon completion of this unit each student will be able to operate and service International diesel engine model 429 while working as a member of a two (2) man team. He will use all appropriate handtools, special tools and shop equipment. These tasks will consist of engine operation followed by service to the fuel system, cooling system and lubricating system. All performance will comply, without deviation, to manufacturer's recommendations as specified in the Job Sheet CM "A" JS 2.2.1.1, Maintenance of International Diesel Engine.

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UNIT 2.4 CUMMINS DIESEL ENGINE MAINTENANCE Contact Hours: 25

Terminal Objective: Upon completion of this unit each student will be able to operate and service the Cummins N.H. 250 diesel engine while using applicable handtools, special tools, and shop equipment. Specifically, he will operate a Cummins diesel engine and service the fuel system, cooling system and scavenging system. All tasks will meet manufacturer's specifications and recommendations without deviation as specified in Job Sheet CM "A" JS 2.4.1.1, Maintenance of Cummins Diesel Engines, without deviation.

Topic 2.4.1 CUMMINS DIESEL ENGINE OPERATION Contact Hours: 4

Enabling Objectives: Upon completion of this topic each student will be able to operate a Cummins N.H. 250 diesel engine. He will prestart check, start, run and secure the engine while monitoring instruments, and interpreting their readings. His performance shall conform to manufacturer's recommendations, without error, as specified in Job Sheet CM "A" JS 2.4.1.1, Maintenance of Cummins Diesel Engines.

Topic 2.4.2 CUMMINS DIESEL ENGINE MAINTENANCE Contact Hours: 21

Enabling Objectives: Upon completion of this topic each student will be able to service a Cummins N.H. 250 diesel engine while using appropriate handtools, special tools, and shop equipment. Specifically, he will service the fuel system, cooling system, lubricating system and scavenging system. All tasks will conform to manufacturer's specifications as specified in the Job Sheet CM "A" JS 2.4.1.1, Maintenance of Cummins Diesel Engines, without deviation.

UNIT 2.5 LD465-1 MULTIFUEL ENGINE MAINTENANCE Contact Hours: 28

Terminal Objective: Upon completion of this unit each student will be able to operate and service the LD465-1 Multifuel engine using appropriate handtools, special tools, and shop equipment. Specifically, he will service the fuel system, cooling system, lubricating system and scavenging system. His performance will conform to manufacturer's specifications as specified in Job Sheet CM "A" JS 2.5.1.1, LD465-1 Multifuel Engine Maintenance, without deviation.

Topic 2.5.1 LD465-1 MULTIFUEL ENGINE OPERATION Contact Hours: 5

Enabling Objectives: Upon completion of this topic each student will be able to prestart check, start, run and secure the LD465-1 Multifuel engine while monitoring instruments and interpreting readings. All performance will conform to manufacturer's recommendations as stated in the Job Sheet CM "A" JS 2.5.1.1, LD465-1 Multifuel Engine Maintenance, without deviation.

Topic 2.5.2 LD465-1 MULTIFUEL ENGINE MAINTENANCE Contact Hours: 23

Enabling Objectives: Upon completion of this topic each student will be able to service the LD465-1 Multifuel engine using appropriate handtools, special tools and shop equipment. Specifically, he will service the fuel system, cooling system, lubricating system and scavenging system. All tasks will conform to manufacturer's specifications as specified in Job Sheet CM "A" JS 2.5.1.1, LD465-1 Multifuel Engine Maintenance, without deviation.

UNIT 3.1 AUTOMOTIVE CHASSIS AND POWER TRAIN MAINTENANCE Contact Hours: 83

Terminal Objective: Upon completion of this unit each student, while working as a member of a two (2) man team, will be able to service automotive chassis and power train components using appropriate handtools, special tools, shop equipment and materials. Specifically, he will service suspension system, power train and brake system, of the M715, 1 1/4 ton, cargo truck. All tasks will conform to manufacturer's specifications, without error, as specified in the Job Sheet CM "A" JS 3.1.1.1, Servicing the Power Train of the M715, 1 1/4 ton Cargo Truck.

Topic 3.1.1 SUSPENSION SYSTEM SERVICE Contact Hours: 13

Enabling Objectives: Upon completion of this topic each student, while working as a member of a two (2) man team, will be able to service suspension system components using appropriate handtools, special tools, and shop equipment. Specifically, he will service tires, tubes, wheels, and steering systems of the M715, 1 1/4 ton cargo truck. All tasks will conform to manufacturer's specifications and recommendations without error as specified in the Job Sheet CM "A" JS 3.1.1.1, Servicing the Power Train of the M715, 1 1/4 Ton Cargo Truck.

Topic 3.1.2 AUTOMOTIVE POWER TRAIN SERVICE Contact Hours: 35

Enabling Objectives: Upon completion of this topic each student, while working as a member of a two (2) man team, will be able to service power train components using handtools, special tools, shop equipment and materials. These tasks will consist of service to clutch, transmission, drive shafts, and drive axles of the M715, 1 1/4 ton cargo truck. All performance will conform to manufacturer's specifications without error as specified in Job Sheet CM "A" JS 3.1.1.1, Servicing the Power Train of the M715 1 1/4 Ton Cargo Truck.

Topic 3.1.3 BRAKE SYSTEM SERVICE Contact Hours: 27

Enabling Objectives: Upon completion of this topic each student will be able to service hydraulic brake system, while working as a member of a two (2) man team. Using appropriate handtools, special tools, and materials and shop equipment. He will replace worn hydraulic system parts and bleed and adjust the system of the M715, 1 1/4 ton cargo truck. All performance will conform to manufacturer's specifications without deviation as specified in Job Sheet CM "A" JS 3.1.1.1, Servicing the Power Train of the M715, 1 1/4 ton Cargo Truck.

Topic 3.1.4 SERVICING THE M715 1 1/4 TON CARGO TRUCK Contact Hours: 8

Enabling Objectives: Upon completion of this topic each student will be able to perform service procedures to the M715, 1 1/4 ton cargo truck. Specifically, he will locate service points, dispense appropriate lubricant, and check fluid levels while using appropriate handtools, lubrication equipment and lubrication orders. All performance will meet manufacturer's specifications as specified in the Job Sheet CM "A" JS 3.1.1.1, Servicing the M715 1 1/4 Ton Cargo Truck.

UNIT 4.1 CRAWLER TRACTOR POWER TRAIN MAINTENANCE Contact Hours: 52

Terminal Objective: Upon completion of this unit each student will be able to: (1) Service the power train and chassis units of the Caterpillar D4D Crawler tractor. .Using appropriate handtools, special tools, shop equipment and oxy-mapp gas outfit, he will remove, disassemble, inspect and replace worn parts, assemble and adjust the master clutch, transmission, steering clutches, final drive/sprocket assembly, bevel gear assembly and track roller frame assembly. All tasks will meet manufacturer's specifications without deviation as specified in Job Sheets CM "A" JS 4.1.1.1, Oxy-mapp Gas Heating and Cutting and CM "A" JS 4.1.2.1, Servicing the D4D Caterpillar Crawler Tractor Power Train, and (2) Adjust the International model 260 Cable Control unit using appropriate handtools ans shop equipment. All adjustments will conform without deviation to manufacturer's specifications as specified in the Job Sheet CM "A" JS 4.1.3.1, Adjusting International Model 260 Cable Control Units.

Topic 4.1.1 OXY-MAPP GAS HEATING AND CUTTING Contact Hours: 6

Enabling Objectives: Upon completion of this topic each student will be able to safely set up, operate and secure oxy-mapp gas welding outfit to accomplish a heating and cutting operation as specified in the Job Sheet CM "A" JS 4.1.1.1, Oxy-Mapp Gas Heating and Cutting, without deviation.

Topic 4.1.2 CONSTRUCTION EQUIPMENT POWER TRAINS Contact Hours: 42

Enabling Objectives: Upon completion of this topic each student will be able to service the power train and chassis units of the Caterpillar D4D Crawler Tractor while using appropriate handtools, special tools, shop equipment and materials. Specifically, he will remove, disassemble, inspect, replace worn parts, assemble, lubricate and adjust the master clutch, transmission, steering clutches, final drive/sprocket, bevel gear assembly and track roller frame assembly. All tasks will meet manufacturer's specifications without deviation as specified in Job Sheet CM "A" JS 4.1.2.1, Servicing the D4D Caterpillar Crawler Tractor Power Train.

Topic 4.1.3 ADJUSTMENT OF INTERNATIONAL MODEL 260 CABLE CONTROL UNIT Contact Hours: 4

Enabling Objectives: Upon completion of this topic each student will be able to adjust the International Model 260 Cable Control Unit using appropriate handtools and shop equipment. All adjustments will conform to manufacturer's specifications without deviation as specified in the Job Sheet CM "A" JS 4.1.3.1, Adjusting the International Model 260 Cable Control Unit.

17. Operation and Maintenance Instructions, Caterpillar D-333 and D-330 Industrial Engines, Form FE045040-02, Caterpillar Tractor Co., Peoria, Illinois 61602.

18. Operation and Maintenance Instructions, Caterpillar D-342 Engine, Form FE31603-9, Caterpillar Tractor Co., Peoria, Illinois 61602.

19. Organizational Direct Support and General Support Maintenance for Model M-715, 1 1/4 Ton, 4 x 4 Cargo Truck TM9-2320-244-34.

20. Organizational Direct Support and General Support, Repair Parts and Special Tool List for Truck, Cargo, 1 1/4 Ton, 4 x 4 M-715, TM9-2320-244-34P.

21. Service Manual for Caterpillar D-4 Tractor, Serial No. 78A1-UP, Caterpillar Tractor Co., Peoria, Illinois 61602.

22. Service Manual International Cable Control Units Form ISS-1513, International Harvester Co., 401 North Michigan Avenue, Chicago, Illinois 60611.

23. Service Manual International 429 Series Diesel Engine, Form ISS1530D, International Harvester Co., 401 North Michigan Avenue, Chicago, Illinois 60611.

24. Service Manual Roosa Master Fuel Injection Pump for International Diesel Engines, Form ISS1042D, International and Hough Construction Equipment, 401 North Michigan Avenue, Chicago, Illinois 60611.

25. Service Training Outline, Cable Control Units, Models 260, 270 and 280, Melrose Tech. Course TE-4, International Harvester Construction Equipment Division, 401 North Michigan Avenue, Chicago, Illinois 60611.

26. The Principles of a Mechanical Governor, Bulletin 983601, Cummins Engine Co.Inc., Columbus, Indiana 47201.

27. V-71 Engines, Detroit Diesel Operator's Manual, Form 6SE215 (Current Series), Detroit Diesel Engine, Division, GM Corp., Detroit, Michigan 48228.

28. Steelworker 3 & 2, NAVPERS 10653-F.

29. 1969 Ford Truck Shop Manual, Vol. Three, Ford Service Publications, Ford Motor Co., Dearborn, Michigan 48207.

30. 1969 Ford Truck Shop Manual, Vol. Two, Ford Service Publications, Ford Motor Co., Dearborn, Michigan 48207.

ANNEX I

TEXTS

1. Aneroids, Cummins, Bulletin No. 985605-R, Cummins Engine Co. Inc., Columbus, Indiana 47201.
2. Automotive Mechanics 6th Edition, McGraw-Hill Book Co.
3. Automotive Electrical Equipment, Seventh Edition, McGraw-Hill Book Co.
4. Construction Mechanic 3 & 2, NAVPERS 10644-F.
5. Cummins Diesel Engines, Construction, Industrial, Industrial Fire Pump, Logging, Mining, Railway, Generator, Operation and Maintenance Manual, Bulletin No. 983711-OE, Cummins Engine Co. Inc., Columbus Indiana 47201.
6. Cummins Tune-up and Trouble-Shooting, Bulletin No. 983643-CE, Cummins Engine Co. Inc., Columbus, Indiana 47201.
7. Detroit Diesel Field Service Data (Military) Form 18SZ51, Detroit Diesel Engine Division, General Motors Corp., Detroit Michigan 48228.
8. Diesel the Modern Power, Fourth Edition, Sixth Printing, General Motors Corp., Detroit Michigan 48228.
9. Direct Support, General Support and Depot Maintenance for Engine Diesel (Multifuel) Turbocharged, Fuel Injected, Water Cooled, 6-cylinder (LDS465-1) and (LD465-1), TM9-2815-210-35.
10. Fluid Power, NAVPERS 16193-B.
11. Get a Clear Picture of Your Turbocharger and -----Form FE035934, Caterpillar Tractor Co., Peoria, Illinois 61602.
12. In-Line 71 Series Detroit Diesel Maintenance, Form 6SE177, Detroit Diesel Engine Division, GM Corp., Detroit, Michigan 48228.
13. Organizational Maintenance Manual for Truck, Cargo, 1 1/4 Ton, 4 x 4, M715, TM9-2320-244-20.
14. Operator's Manual International UDT 429 Engine and Attachments, Form 1-085-250-R1, International Harvester Co., 401 North Michigan Avenue, Chicago, Illinois 60611.
15. Operation and Adjustment, P.T. Fuel System, Bulletin No. 983438-A, Cummins Engine Co. Inc., Columbus, Indiana 47201.
16. Operation and Maintenance Instructions, Caterpillar D-4 Tractor, Serial No. 78A1-UP, 86A1-UP, Form 34887-2, Caterpillar Tractor Co., Peoria, Illinois 61602.

ANNEX II

REFERENCES

1. Department of the Navy Safety Precautions for Shore Activities, NAVSO P-2455 (Current Series).
2. How to Study, TF Staton, McQuiddy Printing Co., Nashville, Tennessee.
3. Management of Transportation Equipment, NAVFAC P-300.
4. NAVCONSTRACENINST 5400.4 (Current Series) (Organizational Manual of NAVCONSTRACEN).
5. Oxyacetylene Handbook, Second Edition, Linde Air Products, Division of Union Carbide, 270 Park Avenue, New York, New York 10017.
6. Construction Battalion Administration, NAVFAC P-315.
7. Direct Support, General Support and Depot Maintenance, (including repair parts and special tools) for Pump, Fuel Metering and Distributing Assembly (American Bosch PSB6A) TM9-2910-226-35.

ANNEX III

TOOLS, EQUIPMENT AND MATERIALS

FSN/MFG. NO.	ITEM	QTY	COST
TOOLS			
55719-VEV-1022-K-B	Automotive Handtools w/cabinet	24 ea.	374.53
	Automotive Shop Tools		
	Battery Shop Tools		
9HE 4910-00-273-3658	Brake Fluid Dispensers	6 ea.	40.13
	Caterpillar Crawler Tractor Tools		
9QZ 5180-oo-592-7141	Caterpillar Diesel Engine Special Tools	3 ea.	295.12
9QL 5180-00-297-8908	Cummins Diesel Engine Special Tools	6 ea.	209.93
	Diesel Engine Handtools		
	Diesel Engine Shop Tools		
	GM Diesel Engine Special Tools		
9CD 4930-00-253-2478	Grease Guns	12 ea.	2.47
	Heavy Equipment Handtools		
	Heavy Equipment Shop Tools and Equipment		
	International Diesel Engine Special Tools		
9GQ 7240-00-255-5996	Lubricating Oil Dispensers	6 ea.	5.56
	Measuring Instruments		
	Tire Shop Tools		
	Welding Shop Handtools	4 sets	
9QG 5180-00-932-5345	Tool Kit Brake Service	6 ea.	47.90

FSN/MFG. NO.	ITEM	QTY	COST
EQUIPMENT (MAJOR)			
	Caterpillar D4D Crawler Tractor	6 ea.	
	Caterpillar D3306 Diesel Engine	3 ea.	
	Caterpillar D342 Diesel Engine	3 ea.	9,200.00
	Cummins NH250 Diesel Engine	6 ea.	
	Cummins PT Fuel Injection Pump	12 ea.	
	Ford 240 CI 6 Cyl Gasoline Engine	12 ea.	
	GM V6-71 Diesel Engine	6 ea.	6,000.00
	GM 6-71 Diesel Engine	6 ea.	
	IHC UDT 429 Diesel Engine	4 ea.	
	IHC Model 260 Power Control Unit	4 ea.	
	LD 465-1 Multifuel Engine	4 ea.	
2CD 2320-00-246-4077	M715 1 1/4 Ton Cargo Truck	12 ea.	8,030.00
9GD 3433-00-076-3261	Oxy-Mapp Gas Cutting Outfit	4 ea.	345.00
2CZ 4930-00-236-0806	Portable Lubrication Unit	1 ea.	6,080.00
2CZ 4940-00-841-9317	Portable Steam Cleaner	1 ea.	2,010.00
95564/20-20	Tire Demounter	2 ea.	423.00
2CD 2320-00-926-0873	2 1/2 Ton M Series 6 x 6 Truck	2 ea.	8,270.00
	5 Ton M Series 6 x 6 Truck	2 ea.	
EQUIPMENT (TEST)			
9LD 6630-00-171-5157	Battery Hydrometer	12 ea.	1.78
70L 4910-00-199-8080	Battery Starter Testers	6 ea.	100.00
1HL 4910-00-241-3081	Compression Tester	12 ea.	19.50
1HC 4910-00-906-0410	Cooling System Pressure Tester	12 ea.	13.00

FSN/MFG. NO.	ITEM	QTY	COST
EQUIPMENT (TEST) (CONT'd)			
9VD 4910-00-199-8125	Tach-Dwell Meter	12 ea.	95.00
9HE 4910-00-937-5724	Timing Light	12 ea.	35.48
9H 4910-00-255-8673	Vacuum Gauge	12 ea.	12.42
MATERIALS (CONSUMABLE)			
	Gasoline and Diesel Engine Parts		
	Batteries		
	Brake System Parts Kit		
	Caterpillar Fuel Filters		
	Caterpillar Air Filters		
	Caterpillar Oil Filters		
	Charging System Components		
9GD 9150-00-057-8977	Chassis Grease		24.90 dr.
9GK 6850-00-285-8012	Cleaning Solvent		20.50 dr.
9AD 2640-00-273-1625	Cold and Hot Patch, Kit		22.24 ea.
	Cranking System Components		
	Cummins Air Filters		
	Cummins Fuel Filters		
	Cummins Oil Filters		
9XO 9140-00-286-5297	Diesel Fuel (Drummed) DF2		8.97 dr.
9GK 9150-00-189-6729	I.C.E. Engine Oil HDO 30		37.10 dr.
9GD 6810-00-297-9540	Distilled Water (5 Gal. Cont.)		3.13 bt.
9GD 4240-00-202-9473	Face Shields		2.09 ea.
	Ford Engine Gasket Sets		
9XO 9130-00-240-8204	Gasoline (Drummed)		12.10 dr.

FSN/MFG. NO.	ITEM	QTY	COST
MATERIALS (CONSUMABLE)	(CONT'D)		
9CK 9150-00-577-5846	Gear Oil EP 90		42.20 dr.
	GM Diesel Air Filters		
	GM Diesel Fuel Filters		
	GM Diesel Oil Filters		
9GD 9150-00-231-9071	Hydraulic Brake Fluid		2.18 gal.
9QZ 5120-00-965-0326	Igniters, Torch		.21 ea.
9QG 5120-00-965-0603	Flint, Igniters		.18 bx.
	Ignition System Components		
	International Air Filters		
	International Fuel Filters		
	International Oil Filters		
9GL 6830-00-935-1125	Mapp Gas (Bulk)		.30 lb.
9GD 8120-00-350-5477	Cylinder, Mapp Gas	4 ea.	20.00
	Multifuel Engine Air Filters		
	Multifuel Engine Oil Filters		
	Multifuel Engine Fuel Filters		
9GL 6830-00-169-0805	Oxygen (Welding)		.01 cu. ft.
9GD 8120-00-151-9758	Cylinder Oxygen	4 ea.	25.00 ea.
	Sheet Metal (Scrap)		
7030-269-1272	Sweeping Compound, Oil and Water		1.40 bg.
	Tires		
	Tubes		
9AH 2640-922-6921	Tubeless Tire Repair Kits		36.03
9DD 8415-268-7860	Welding Gloves	8 ea.	3.72 pr.

FSN/MFG. NO.	ITEM	QTY	COST
MATERIALS (CONSUMABLE)	(CONT'D)		
9DD 8415-00-250-2531	Apron, Welding	8 ea.	10.00 ea.
9GD 4240-00-203-3804	Welding Goggles (Lens Shade 6)	8 ea.	1.25 ea.
9CD 4720-00-834-2560	Welding Hose	4 ea.	27.80 ea.
9GC 3439-00-270-6047	Welding Tip Cleaner	4 ea.	1.46 ea.
9GD 3433-00-076-3261	Torch Outfit, Cutting And Welding	4 ea.	345.00 ea.
9GD 3920-00-802-8313	Cart, Cutting and Welding Outfit	4 ea.	72.00 ea.
	Welding Tips		
9QG 7920-00-401-8034	Wiping Rags		2.45 bd.
5210-00-640-6177	Plastigage .001 - .003		

ANNEX IV

TRAINING AIDS AND DEVICES

FILMS

1.	MA1672Q	Automotive Trouble-Shooting, Part 15, The Clutch (21 min.) Obsolete.
2.	MN1730A	Elementary Hydraulics, Part I, Derivation of Pascal's Law (16 min.).
3.	MN1730C	Elementary Hydraulics, Part I, Application of Pascal's Law (12 min.).
4.	MN1730E	Elementary Hydraulics, Liquids in Motion (13 min.).
5.	MN1921G	Safety for Welders (17 min.).
6.	MA3739	Automotive Gears, Principles of Operation (25 min.) obsolete.
7.	MC7889	The Tools and Rules for Precision Measuring (30 min.).
8.	MN8016A	Basic Electricity, The Electron Theory (5 min.).
9.	MN8016B	Basic Electricity, How Magnets Produce Electricity (3 min.).
10.	MA8070	Planetary Gears, Principles of Operation, Part I, Single Sets (18 min.).
11.	MC8146	The Gamblers (20 min.).
12.	MN8594A	Direct Current Generators, Theory of Operation (16 min.).
13.	MC8622B	Boss of the Bulldozers, Caterpillar Tractor Co., (C 18mm).
14.	MA8886	Carburetor Principles of Operation (25 min.).
15.	MC9172A2	A Matter of Time, Caterpillar Tractor Co., (23 min.).
16.	MN9757	Naval Construction Forces (23 min.) Color.
17.	MV9861	Oxyacetylene Cutting Manual (9 min.).
18.	MH10017	It Can Happen, International Harvester Co. (20 min.) Color.
19.	MC10417	ABC of Diesel Engines (20 min.).
20.	MN8594B	Direct Current Motors, Theory of Operation (10 min.).
21.	MN44A	Diesel Engine Governors, Part 1 (12 min.).

FILMS (Commercial; Non-Navy, Non-Government)

1.	76S	Short Cut, New Tools and Methods, Caterpillar Tractor Co. (C 20 min.).
2.	OE483	Hydraulic Brake Systems.
3.	9051	Boss of the Bulldozer, Caterpillar Tractor Co. (C 20 min.).
4.	985566M	Turbocharger, Cummins Engine.

FILMS (Commercial; TAMARS Numbers Assigned)

1.	ABC-001	ABC Of Handtools, Part 1, GM Corp. (C 18 min.).
2.	ABC-002	ABC of Handtools, Part 3, GM Crop. (C 15 min.).
3.	ABC-003	ABC of Automotive Engines, GM Corp. (21 min.).
4.	CAS-001	The Case of the Slippery Oil, Dana Corp. (C 40 min.).
5.	COO-001	Cooling System, Ethyl Corp. (C 20 Min.).
6.	OPE-001	Operation Hour Glass, Cummins Engine, (C 27 min.).
7.	OPE-010	Operation and Maintenance, Part 1, Bendix-Westinghouse Air Brakes (C 24 min.).
8.	LET-001	Let'er Roll, Timken Roller Bearing Co. (50 min.).
9.	ROL-002	The Roll of Drums, Caterpillar Tractor Co. (20 min.)
10.	POW-009	Power Train (13 min.).

FILMS (Government, Non-Navy)

1.	TF9-3276	Truck Cargo, 2 1/2 Ton, 6 x 6 M35A1 (Multi-Fuel Engine, Introduction and Operation) (13 min.).
2.	TF9-3469	Multi-Fuel Engine Principles, Model LDS472-2 (24 min.).

SLIDE FILMS (Commercial)

1.		American Bosch PSB6A Fuel Pump.
2.	Module 6001	Gasoline Engine, Principles of Operation, Ford Motor Co.
3.	SC8620C	IHC Cable Control Units.
4.	TE-4	IHC Cable Control Units.
5.	9010K	Introduction to Automotive Electrical Systems, Delco-Remy.

SLIDE FILMS (Commercial) (Cont'd)

6.	9011K	Delcotron Generator and the Charging Circuit, Delco-Remy.
7.	9020K	20,000 Volts Under the Hood, Delco-Remy.
8.	9025K	The Cranking Circuit, Delco-Remy.
9.		Roosa-Master Fuel Injection System, IHC Diesel Engines.
10.		GM 71 Series Diesel Engine Construction.
11.		Multi-Fuel Engine Construction.
12.	Module 4001	Car Rear Axle Principles of Operations, Ford Motor Co.
13.	CT-25	Torque Converter, International Harvester Co. (Set of 56 slides).
14.	CT-26	Power Shift, International Harvester Co. (Set of 80 slides).
15.	JEGO-1104	Truck Type Tractors, Caterpillar Tractor Co. (Set of 65 slides).
16.	JEGO-1106	Sprocket Removal and Installation, Caterpillar Tractor Co. (Set of 50 Slides).
17.	JEGO-1706	Safety and You, Caterpillar Tractor Co. (Set of 19 slides).
18.	JEOO-1601	Direct Drive Transmission, Caterpillar Tractor Co. (Set of 50 slides).
19.	JEOO-1602	Clutches, Part 1, Caterpillar Tractor Co. (Set of 63 slides).
20.	JEOO-1603	Clutches, Part 2, Caterpillar Tractor Co. (Set of 46 slides).
21	JEOO-1604	Power Shift, Caterpillar Tractor Co. (Set of 54 slides).
22.	JEOO-1606	Final Drives, Part 1, Caterpillar Tractor Co. (Set of 43 slides),

SLIDES (Individual)

1. CM "A" S 4.1.2.1, "D-8 Crawler Tractor w/o Blade".
2. CM "A" S 4.1.2.2, "MRS-I-110 Wheeled Tractor w/o Attachments".
3. CM "A" S 4.1.2.3, "IHC Wheeled Tractor w/o Attachments".
4. CM "A" S 4.1.2.4, "D-7 Crawler Tractor with Std. Dozer Blade".

SLIDES (individual) (Cont'd)

5. CM "A" S 4.1.2.5, "D-8 Crawler Tractor with Angle Dozer Blade".

6. CM "A" S 4.1.2.6, "955 Crawler Front End Loader w/std. Bucket".

7. CM "A" S 4.1.2.7, "MRS-S-110 Scraper with MRS-I-110 Tractor".

8. CM "A" S 4.1.2.8, "Galion 118-T, Motor Grader".

9. CM "A" S 4.1.2.9, "3 Axle Road Roller".

10. CM "A" S 4.1.2.10A, "Sheepsfoot Roller (Towed)".

11. CM "A" S 4.1.2.10B, "Wobbly Wheel Roller (Towed)".

12. CM "A" S 4.1.2.10C, "Grid Roller (Towed)".

13. CM "A" S 4.1.2.10D, "Wobbly Wheel Roller (Towed)".

14. CM "A" S 4.1.2.11, "Crawler Mounted Crane".

15. CM "A" S 4.1.2.12, "Truck Mounted Crane".

16. CM "A" S 4.1.2.13, "Wheeled Mounted Crane".

17. CM "A" S 4.1.2.14, "Air Compressor, 600 CFM, Rotary".

18. CM "A" S 4.1.2.15, "Master Clutch Components".

19. CM "A" S 4.1.2.16, "Master Clutch Brake".

20. CM "A" S 4.1.2.17, "Transmission Gear Arrangement".

21. CM "A" S 4.1.2.18, "Transmission Gearshift Mech.".

22. CM "A" S 4.1.2.19a, b, c, d, e, f, "Transmission Interlock".

23. CM "A" S 4.1.2.20, "Steering Clutch Components".

24. CM "A" S 4.1.2.21, "Steering Clutch Brake Mechanism".

25. CM "A" S 4.1.2.22, "Steering Clutch Exposed View".

26. CM "A" S 4.1.2.23, "Steering Clutch Assembly Check".

27. CM "A" S 4.1.2.24, "Final Drive Operation".

28. CM "A" S 4.1.2.25, "Final Drive and Cover Assembly".

SLIDES (Individual) (Cont'd)

29. CM "A" S 4.1.2.26. "Track and Roller Frame Group".

30. CM "A" S 4.1.2.27, "Track and Roller Frame Link and Pins".

31. CM "A" S 4.1.2.28, "Track and Roller Frame Pins and Links".

32. CM "A" S 4.1.2.29a, b, "Track and Roller Frame Link and Pins".

33. CM "A" S 4.1.2.30a, b, "Track Shoes (Types)".

34. CM "A" S 4.1.2.31, "Track Adjustments".

35. CM "A" S 4.1.2.32, "Track Roller Lubrication".

36. CM "A" S 4.1.2.33, "Track Recoil Mechanism".

37. CM "A" S 4.1.2.34, "Track Frame Alignment".

TRANSPARENCIES

1. Module 7001 Car 3-speed Manual Shift Transmission and Overdrive Principles of Operation, Ford Motor Co.

2. Module 7001 Car and Truck Clutches, Principles of Operation, Ford Motor Co.

CHARTS (Commercial)

1. Section "A" Fundamentals of Electricity and Magnetism, Delco-Remy.

2. Section "B" Energizers and Batteries, Delco-Remy.

3. Section "C" Cranking Motors, Delco-Remy.

4. Section "D" Ignition System, Delco-Remy.

5. Section "E" Generators - D.C. Type, Delco-Remy.

6. Section "K" Fundamentals of Delcotron Generators - A.C. Type, Delco Remy.

7. Engine Cooling System, End View, Cummins Engine Co.

8. Engine Cooling System, Side View, Cummins Engine Co.

CHARTS (Commercial) (Cont'd)

9. Engine Lubricating System, End View, Cummins Engine Co.

10. Engine Lubricating System, Side View, Cummins Engine Co.

11. Module 4200 Car Rear Axle Diagnosis, Ford Motor Co.

12. Module 6002 Gasoline Engine Diagnosis, Ford Motor Co.

13. Module 7002 Car and Truck Clutches, Diagnosis and Adjustment, Ford Motor Co.

14. Module 7203 Truck 4 and 5 speed Manual Transmission, Principles of Operations, Ford Motor Co.

15. P. T. Fuel System Operation, Cummins Engine Co.

16. P. T. Fuel System Flow, Cummins Engine Co.

LOCALLY PREPARED MATERIALS

INFORMATION SHEETS

1. CM "A" IS 1.1.2.1 "Study Techniques".
2. CM "A" IS 1.1.3.1 "Safety Policies".
3. CM "A" IS 1.2.2.1 "Maintenance Of Lead Acid Storage Batteries".
4. CM "A" IS 1.2.2.2 "Basic Principles of Electricity".
5. CM "A" IS 1.2.2.3 "Electrical Circuits".
6. CM "A" IS 1.2.3.1 "General Housekeeping".
7. CM "A" IS 1.2.4.1 "Measuring Instruments".
8. CM "A" IS 1.2.4.2 "Fractions".
9. CM "A" IS 1.2.4.3 "Conversion Chart".
10. CM "A" IS 2.1.1.1 "Magnetos".
11. CM "A" IS 3.1.1.1 "The Power Train of the M715 1 1/4 Ton Cargo Truck".

JOB SHEETS

1. CM "A" JS 1.2.3.1 "Gasoline Engine Disassembly, Inspection and Assembly".
2. CM "A" JS 1.2.6.1 "Gasoline Engine Diagnosis and Adjustment".
3. CM "A" JS 2.1.1.1 "Maintenance of Caterpillar Diesel Engines".
4. CM "A" JS 2.2.1.1 "Maintenance of IHC UDT 429 Engines".
5. CM "A" JS 2.3.1.1 "Maintenance of General Motors Diesel Engines".
6. CM "A" JS 2.4.1.1 "Maintenance of Cummins NH Diesel Engines".
7. CM "A" JS 2.5.1.1 "Maintenance of LD 465-1 Multifuel Engines".
8. CM "A" JS 3.1.1.1 "Servicing the Power Train of the M715 1 1/4 Ton Cargo Truck".
9. CM "A" JS 4.1.1.1 "Oxy-Mapp Gas Heating and Cutting".
10. CM "A" JS 4.1.2.1 "Servicing the D4D Crawler Tractor".
11. CM "A" JS 4.1.3.1 "Adjusting the IHC Model 260 Power Control Unit".

WORK SHEETS

1. CM "A" WS 1.2.4.1 "Mathematics Work Sheet".

PROBLEM SHEETS

1. CM "A" PS 3.1.1.1 "Suspension Field Test (Series)".
2. CM "A" PS 3.1.2.1 "Power Train Field Test (Series)".
3. CM "A" PS 3.1.3.1 "Brake Service Field Test (Series)".

ANNEX V

TRAINING AIDS EQUIPMENT

DEVICES

1.	NP-17008	Device 6A2 Engine Internal Combustion, Electrically Operated, $9195.00
2.		Projectors, 16mm sound.

DEVICES (Non-Navy)

1.	D-315	Caterpillar Diesel Engine (Cutaway) $8700.00.
2.	GM 3-71	Diesel Engine (Cutaway).
3.	Cummins	P. T. Pump (Cutaway).
4.	American Bosch	Model PSB6A Fuel Injection Pump (Cutaway).
5.	American Bosch	Manual 5 speed Transmission (Cutaway).
6.	American Bosch	Differential Assembly, Double Reduction (Cutaway).
7.	American Bosch	Air Brake System (mounted onboard) $2445.00
8.	International	Model 260 Cable Control Unit (Cutaway).
9.	Roosa-Master	Fuel Injection Pump (Cutaway).
10.	Caterpillar	Turbocharger (Cutaway).
11.		35mm projectors, tape recorders.

ANNEX VI

FORMS

1. Equipment Work Order (NAVFAC 6-11200/41 Rev. 5-69) 0105-002-5326.

2. Shop Repair Order (continuation sheet) (NAVFAC 9-11200/3B (9-67)) 0105-004-1020.

Master Schedule

3.1.1	C	20.5 21.0	Suspension System Service	24/1
1.0.3	F	21.5	Aerobics	24/1

FOURTH DAY

3.1.1	C	22	Suspension System Service	24/1
	S	23		6/1
		24		
		25		
		26		
	C	27		24/1
	S	28		6/1

NINTH WEEK (Cont'd)

TOPIC NO.	TYPE	PERIOD	TITLE	RATIO
FIFTH DAY				
3.1.1	S	29	Suspension System Service	6/1
	C	30		24/1
	S	31		6/1
1.0.21	C	32	Code of Conduct, Part I	24/1
1.0.22	C	33	Code of Conduct, Article I	24/1
1.0.23	C	34	Code of Conduct, Article II	24/1
1.0.17	F	35.0	Close Order Drill	24/1
1.0.3	F	35.5	Aerobics	24/1
TENTH WEEK				
FIRST DAY				
3.1.1	S	1	Suspension System Service	6/1
	C	2		24/1
3.1.2	C	3	Automotive Power Train Service	24/1
		4		
	S	5		6/1
	C	6		24/1
	S	7.0		6/1
1.0.3	F	7.5	Aerobics	24/1
SECOND DAY				
3.1.2	S	8	Automotive Power Train Service	6/1
		9		
		10		
		11		
		12		
		13		
	C	14		24/1
THIRD DAY				
3.1.2	S	15	Automotive Power Train Service	6/1
		16		
		17		
		18		
		19		
		20		
	C	21.0		24/1
1.0.3	F	21.5	Aerobics	24/1

TENTH WEEK (Cont'd)

TOPIC NO.	TYPE	PERIOD	TITLE	RATIO
FOURTH DAY				
3.1.2	S	22	Automotive Power Train Service	6/1
		23		
		24		
		25		
		26		
		27		
		28		
FIFTH DAY				
3.1.2	S	29	Automotive Power Train Service	6/1
		30		
		31		
1.0.24	C	32	Code of Conduct, Article III	24/1
1.0.25	C	33	Code of Conduct, Article IV	24/1
1.0.26	C	34	Code of Conduct, Article V	24/1
1.0.17	F	35.0	Close Order Drill	24/1
1.0.3	F	35.5	Aerobics	24/1
ELEVENTH WEEK				
FIRST DAY				
3.1.2	S	1	Automotive Power Train Service	6/1
		2		
		3		
		4		
		5		
	C	6		24/1
	S	7.0		6/1
1.0.3	F	7.5	Aerobics	24/1
SECOND DAY				
3.1.2	C	8.0	Automotive Power Train Service	24/1
3.1.3	C	8.5	Brake System Service	24/1
		9		
		10		
		11		
		12.0		
	S	12.5		6/1
		13		
		14		

ELEVENTH WEEK (Cont'd)

TOPIC NO.	TYPE	PERIOD	TITLE	RATIO
THIRD DAY				
3.1.3	S	15 16 17 18 19	Brake System Service	6/1
	C	20		24/1
	S	21.0		6/1
1.0.3	F	21.5	Aerobics	24/1
FOURTH DAY				
3.1.3	S	22 23 24 25 26	Brake System Service	6/1
	C	27		24/1
	S	28		6/1
FIFTH DAY				
3.1.31	S	29 30 31	Brake System Service	6/1
1.0.27	C	32	Code of Conduct, Article VI	24/1
1.0.29	C	33	Basic Organization of our Government	24/1
1.0.28	C	34	History and Formation of our Government	24/1
1.0.17	F	35.0	Close Order Drill	24/1
1.0.3	F	35.5	Aerobics	24/1
TWELFTH WEEK				
FIRST DAY				
3.1.3	S	1 2 3	Brake System Service	6/1
	C	4		24/1
3.1.4	C	5 6	Servicing the M715 1 1/4 Ton Cargo Truck	24/1
	S	7.0		6/1
1.0.3	F	7.5	Aerobics	24/1

TWELFTH WEEK (Cont'd)

TOPIC NO.	TYPE	PERIOD	TITLE	RATIO
SECOND DAY				
3.1.4	S	8	Servicing the M715 1 1/4 Ton Cargo Truck	6/1
		9		
		10.0		
	C	10.5		24/1
	S	11		6/1
	C	12		24/1
		13.0		
4.1.1	C	13.5	Oxy-Mapp Gas Cutting	24/1
	S	14		6/1
THIRD DAY				
4.1.1	S	15	Oxy-Mapp Gas Cutting	6/1
		16		
		17		
	C	18		24/1
		19.0		
4.1.2	C	19.5	D4D Crawler Tractor	24/1
		20		
		21.0		
1.0.3	F	21.5	Aerobics	24/1
FOURTH DAY				
4.1.2	C	22	D4D Crawler Tractor	24/1
		23		
		24		
		25		
	S	26		6/1
		27		
		28		
FIFTH DAY				
4.1.2	S	29	Servicing the D4D Crawler Tractor	6/1
		30		
		31		
1.0.30	C	32	Function of Legislative Branch	24/1
1.0.31	C	33	Function of Executive Branch	24/1
1.0.32	C	34	Function of Judicial Branch	24/1
1.0.17	F	35.0	Close Order Drill	24/1
1.0.3	F	35.5	Aerobics	24/1

THIRTEENTH WEEK

TOPIC NO.	TYPE	PERIOD	TITLE	RATIO
FIRST DAY				
4.1.2	S	1	Caterpillar D4D Crawler Tractor	6/1
		2		
		3		
		4		24/1
	C	5		6/1
	S	6		
		7.0		24/1
1.0.3	F	7.5	Aerobics	
SECOND DAY				
4.1.2	S	8	Caterpillar D4D Crawler Tractor	6/1
		9		
		10		
		11		
		12		24/1
	C	13		
		14		
THIRD DAY				
4.1.2	S	15	Caterpillar D4D Crawler Tractor	6/1
		16		
		17		
		18		
		19		
		20		
		21.0		24/1
1.0.3	F	21.5	Aerobics	
FOURTH DAY				
4.1.2	S	22	Caterpillar D4D Crawler Tractor	6/1
		23		
		24		
		25		
		26		24/1
	C	27		6/1
	S	28		

THIRTEENTH WEEK (Cont'd)

TOPIC NO.	TYPE	PERIOD	TITLE	RATIO
FIFTH DAY				
4.1.2	S	29	Caterpillar D4D Crawler Tractor	6/1
	C	30		24/1
		31		
1.0.33	C	32	American Foreign Policy	24/1
1.0.34	C	33	The Declaration of Independence	24/1
1.0.36	C	34	Petty Officer Leadership	24/1
1.0.17	F	35.0	Close Order Drill	24/1
1.0.3	F	35.5	Aerobics	24/1
FOURTEENTH WEEK				
FIRST DAY				
4.1.3	C	1	International Model 260 Cable Control Unit	24/1
	S	2		6/1
		3		
	C	4		24/1
		5	Admin	
		6		
		7.0		
1.0.3	F	7.5	Aerobics	24/1
SECOND DAY				
		8	Admin	
		9		
		10		
		11		
		12		
		13		
		14		
THIRD DAY				
		15	Graduation	

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8-6

CONSTRUCTION MECHANIC SCHOOL

CLASS "A"

INSTRUCTOR GUIDES

PHASE 3

Automotive Chassis and Power Train Maintenance

NAVAL CONSTRUCTION TRAINING CENTER
PORT HUENEME, CALIFORNIA 93043
CONSTRUCTION MECHANIC "A" SCHOOL TRAINING COURSE A-610-0022

Classification: Unclassified

Topic: Suspension System Service

Average Time: 5 Periods (Class), 8 Periods (Pract)

Instructional Materials:

A. Texts:

1. Automotive Mechanics, 6th edition, McGraw-Hill Book Co., chapters 37 and 39.
2. Organizational Direct Support and General Support Maintenance for Model M715, 1 1/4 Ton, 4 x 4 Cargo Truck, TM9-2320-244-24, pp. 195-200.
3. Principles of Automotive Vehicles, TM9-8000.

B. References: None.

C. Tools, Equipment and Materials:

1. Tools:
   a. Automotive shop tools.
   b. Tire shop tools.
   c. Shop equipment.
   d. Automotive handtools.

Terminal Objective: Upon completion of this unit each student, while working as a member of a two (2) man team, will be able to service automotive chassis and power train components using appropriate handtools, special tools, shop equipment and materials. Specifically, he will service suspension system, power train and brake system of the M715 1 1/4 ton Cargo Truck. All tasks will conform to manufacturer's specifications without error, as specified in the Job Sheet, CM "A" JS 3.1.1.1, "Servicing the Power Train of the M715, 1 1/4 Ton Cargo Truck".

Enabling Objectives: Upon completion of this topic each student, while working as a member of a two (2) man team, will be able to service suspension system components using appropriate handtools, special tools, and shop equipment. Specifically, he will service tires, tubes, wheels and steering systems of the M715 1 1/4 Ton Cargo Truck. All tasks will conform to manufacturer's specifications and recommendations without error as specified in the Job Sheet CM "A" JS 3.1.1.1, "Servicing the Power Train of the M715, 1 1/4 Ton Cargo Truck".

Criterion Test: While working as a member of a two (2) man team, service suspension system components using appropriate handtools, special tools, and shop equipment, service steering system, tires, tubes and wheels of M715 1 1/4 ton Cargo Truck with all tasks conforming to manufacturer's specifications and recommendations without error as specified in job sheet.

2. Equipment:

   a. Major.

      (1) M715 1 1/4 ton cargo truck (12 each).

      (2) Tire demounter (2 each).

      (3) Dynamic Wheel balancing machines (5 each).

3. Materials (consumable).

   a. Tires.

   b. Tubes.

   c. Cold and hot patches.

   d. Tubeless tire repair kits.

   e. Cleaning solvent.

   f. Wiping rags.

   g. Gasoline.

D. Training Aids and Devices:

1. Locally Prepared Material.

   a. Information sheet.

      (1) CM "A" IS 3.1.1.1, "Excerpts of M715 Maintenance Manual".

Homework: Read:

1. Automotive Mechanics, 6th edition, chapters 37, 38 and 39.

2. TM9-2320-244-24, Maintenance of M715 1 1/4 Ton Cargo Truck, pp. 195-200.

3. TM9-8000, Principles of Automotive Vehicles, chapter 18, pages 370-373 and pages 381-384, chapter 19, pages 389-398, and chapter 20, pages 402-407.

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b. **Job sheet.**

(1) CM "A" JS 3.1.1.1, "Servicing the Power Train of the M715 1 1/4 Ton Cargo Truck".

c. **Problem sheet.**

(1) CM "A" PS 3.1.1.1, "Suspension".

E. **Training Aids Equipment:** None.

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OUTLINE OF INSTRUCTION	INSTRUCTOR ACTIVITY	STUDENT ACTIVITY
I. Introduction to the lesson.		
A. Establish contact.	I.A. Introduce self and topic.	
1. Name:		
2. Topic: Suspension System Service		
B. Establish readiness.	I.B. Motivate student.	
1. Purpose.		
2. Assignment.		
C. Establish effect.	I.C. Bring out need and value of material being presented.	
1. Value.	1. Issue textbooks.	
a. Pass course.		
b. Perform better on the job.	(a) TM9-8000, Principles of Automotive Vehicles.	
c. Get advanced.	(b) Automotive Mechanics, sixth edition.	
d. Be a better construction mechanic.		
D. Overview:	I.D. State learning objectives. 1. State information and materials necessary to guide student.	I.D. Student crew leaders keep tool locker keys until the end of auto chassis phase.
1. The suspension system is the backbone of the vehicle and is the suspension base of the steering units and wheels. The springs are anchored or suspended from the frame. The points of suspension are subject to wear and consequently need service and replacement when wear exceeds certain limits.	2. Assign students to training bays and issue tool locker keys.	

OUTLINE OF INSTRUCTION	INSTRUCTOR ACTIVITY	STUDENT ACTIVITY
II. Presentation.	II. Use current textbooks issued to students for reference of instruction and to assist the student at taking notes.	II. Follow instructors discussion, take notes and turn to pages as directed by instructor.
A. Frames.	II.A. Use training charts or transparencies to explain the parts of the frame.	
1. Functions. a. Support for body and other chassis units. 2. Construction and nomenclature. a. Side members (rails). (1) Heaviest part of frame. (2) Channel or box design. b. Cross members. (1) Channel or tubular design. (2) Connects side rails rigidly together. c. Gusset plates. (1) Angular piece of metal for strengthening angles or corners for frame where cross members are secured to side members. (2) Riveted or welded.	II.A.1. Explain unit body construction for quieter ride.	

OUTLINE OF INSTRUCTION	INSTRUCTOR ACTIVITY	STUDENT ACTIVITY
B. Springs.		
1. Function and nomenclature. a. Support the frame and body as well as the load. b. Absorption of road shocks. c. Maintain axle alignment, transfer drive thrust and receive torque reaction on some vehicles.	II.B.1. Have students refer to text TM9-8000, pages 371-372 to view illustrations of laminated leaf springs and spring shackles.	II.B.1. Refer to pages as directed by instructor and follow discussion.
2. Types of spring assemblies. a. Laminated leaf (multileaf). (1) Nomenclature. (a) Laminated-leaf springs consist of a series of flat steel plates of varying lengths, placed on top of each other. (b) Spring clips (U bolts). 1. Connects springs to axle housing. (c) Spring center bolt. 1. Secures spring leafs together. 2. Maintains spring leafs in proper alignment.	II.B.2. Have students refer to text Automotive Mechanics, 6th edition, chapter 37 to view illustration of automotive springs and suspension.	II.B.2. Refer to pages as directed by instructor and follow discussion.

OUTLINE OF INSTRUCTION	INSTRUCTOR ACTIVITY	STUDENT ACTIVITY
(d) Spring shackles to frame spring hangers.		
1. Connect springs to frame spring hangers.		
2. Allow for shortening and lengthening of springs.		
b. Single leaf.		
(1) Made of single steel plate which is heavier at the center and tapered to the two ends.		
c. Overload leaf springs.	II.B.2.c. Have students refer to text TM9-8000, page 382 to view illustration of auxiliary spring.	II.B.2.c. Locate pages of text as directed by instructor and follow discussion.
(1) Used in conjunction with laminated leaf spring assembly of larger trucks.		
d. Coil (independent wheel suspension).		
(1) Coil spring may be located between upper and lower control arms.		
(2) Or coil spring may be located above upper control arm.		
e. Torsion bar (independent wheel suspension).		
(1) Steel bar that twists lengthwise for spring action.		
(2) Utilizes elasticity of steel.		

OUTLINE OF INSTRUCTION	INSTRUCTOR ACTIVITY	STUDENT ACTIVITY
(3) Mounted in front of lower control arm at one end, and at the frame on opposite end.		
f. Twin I-beam (independent wheel suspension).		
(1) Front wheel is supported at the ends by a separate "I" beam.		
(2) Opposite ends of the "I" beams are attached to the frame by pivots.	II.B.2.f.(2) Have class refer to Automotive Mechanics, 6th edition, pages 466, 468, and 472 to view illustrations of spring assemblies.	II.B.2.f.(2) Turn to pages of text and follow discussion.
3. Types of spring suspension.		
a. Three basic types of wheel suspension systems.		
(1) Beam type front axles.		
(a) Beam type front axle on which the wheels are mounted on each end.		
(b) The front end is supported by leaf springs between the axle and frame.		
(c) Steering knuckle is supported by the kingpin and axle beam.		
(d) Common on most truck front ends.		

(e) Both wheels are mounted to the ends of a rigid axle if one wheel receives a jar or jolt, the whole suspension system, includ- the axle, is effected.

(2) Independent - suspension type.

(a) Varies according to the make of vehicle.

(b) Each wheel is supported independently by a coil spring, torsion bar or twin "I" beam.

(c) Most cars today use ball joints to connect the wheel spindle (steering knuckle) to a control arm.

(d) Some cars still use a kingpin to connect the wheel spindle (steering knuckle) to the steering knuckle support arm.

(e) The steering knuckle support arm connects to the upper and lower suspension or control arm.

(f) Each wheel is individually supported and free to move without affecting the other wheel

OUTLINE OF INSTRUCTION	INSTRUCTOR ACTIVITY	STUDENT ACTIVITY
(3) Bogie suspension type (gear). (a) Used on dual tandem trucks. (b) Uses torque rod assemblies. (c) Springs are mounted on spring seats. (d) Spring seats hold springs securely at center section and oscillate freely on the tube.	II.B.3.a.(3) Direct class to text TM9-8000, chapter 18 and refer to illustrations as discussed.	II.B.3.a.(3) Turn to pages of text and participate in discussio
4. Spring service. a. Lubrication. (1) Generally no lubrication is used on spring surfaces. (2) Some leaf springs have a rubber or nylon insert between the leaves of the spring to prevent noise and wear. (3) Spring shackles use chassis lube on metal bushing and use rubber lube on rubber bushing.	II.B.4. Have students refer to TM9-8000, page 380 and Automotive Mechanics, 6th edition, pages 474-475.	II.B.4. Refer to pages of text as directed by instructor.
C. Shock absorbers (direct acting). 1. Function and nomenclature.		

OUTLINE OF INSTRUCTION	INSTRUCTOR ACTIVITY	STUDENT ACTIVITY
a. Regulate the rebound and compression of the springs, preventing sudden jolts and bounces being transmitted to vehicle body.		
b. Helps to maintain roadability.		
c. Sealed unit with hydraulic fluid.		
(1) Fluid in the shock absorbers is moved one way or the other through small valves within the assemblies by a piston rod.		
2. Shock absorber maintenance.		
a. Replacing shocks.		
(1) Always check opposite shock of a pair to make certain both have the same resistance.		
(2) Replace both shocks of a pair.		
(3) Use only correct type shocks.		
(4) Be sure rock shield is facing down.		
(a) To prevent dirt, etc. from entering area around piston rod.		
D. Steering units.		
1. Types and operation.	II.D.1. Have class refer to TM9-8000, page 403 and refer to illustrations of steering system.	II.D.1. Refer to pages as directed by instructor

OUTLINE OF INSTRUCTION	INSTRUCTOR ACTIVITY	STUDENT ACTIVITY
a. Fifth wheel.		
(1) Serves as a central pivot for the entire front axle.		
(2) Used on trailers and other towed vehicles.		
b. Ackerman.		
(1) Wheels are mounted on individual pivots and connected together by means of steering linkage.		
(2) Steering linkage causes the wheels to rotate together about their pivots.		
(3) Used on self-propelled vehicles.		
2. Principle parts and nomenclature (Ackerman).	II.D.2. Have students refer to text TM9-8000, page 404-405 to illustration of steering members and various steering gears.	II.D.2. Turn to pages of texts as directed by instructor.
a. Steering wheel.		
b. Steering column.		
(1) Hollow shaft.		
c. Steering shaft and worm gear.		
(1) Solid shaft inside steering column.		
(2) Has a worm gear machined, as an integral part of the lower shaft.		

(3) Steering wheel mounted on upper end.

d. Cross shaft and sector.

(1) Cross shaft is also called Pitman arm shaft.

(2) Method of gearing the steering shaft to the cross shaft varies considerably with different types of steering gears.

e. Steering gear housing.

(1) Bolted solid to frame of vehicle.

(2) Provides means for making adjustments to steering gear.

(3) Contains oil for lubrication.

f. Pitman arm.

(1) Splined to cross shaft.

(2) Has a ball stud on other end to connect with drag link.

g. Drag link.

(1) Made in tubular or rod form.

(2) Housing on one end to receive the ball end of the Pitman arm.

OUTLINE OF INSTRUCTION	INSTRUCTOR ACTIVITY	STUDENT ACTIVITY
(a) Contains springs to cushion shock and prevent transmission to the steering gear.		
(b) Other end may be the same or made like a tie rod end.		
(c) Both ends may be like tie rod ends.	II.D.2.g.(2)(c) Explain function and construction of steering connecting unit using illustrations in text. Show students various steering arrangements in Automotive Mechanics, 6th edition, pages 483 and 484.	II.D.2.g.(2)(c) Refer to pages of text as directed by instructor and participate in discussion.
NOTE: The parts of the steering system already covered will be found on most vehicles in the order covered.		
NOTE: The parts to be covered will be found in some combination on most vehicles, but not necessarily will all parts be found on one vehicle.		
h. Bell crank, intermediate knuckle arm or idle arms.		
(1) One end pivoted to frame.		
(2) Drag link and tie rods connected to other end.		
i. Steering knuckle arms.		
(1) Bolted to steering knuckles.		
(2) Sometimes double arms on one side of vehicle - one drag link and one for tie rod.		

OUTLINE OF INSTRUCTION	INSTRUCTOR ACTIVITY	STUDENT ACTIVITY
j. Steering knuckle.		
(1) Spindle shaft is integral with steering knuckle.		
k. Steering knuckle pivots.		
(1) King pin or ball joints.		
l. Tie rods.		
(1) Used to connect the steering knuckles together.		
(2) Generally located behind the front wheels, but may be found in front, as on the jeep.		
(3) The ends of tie rods are threaded to receive and adjustable ball joint socket type tie rod end.		
E. Types of steering gear assemblies.	II.E.1. Use actual steering gear parts to show the action that takes place in the steering gear.	II.E.1. Participate in discussion and take notes.
1. Worm and sector.		
a. Worm on lower end of steering shaft.		
b. Cross shaft carries a sector which is engaged with the worm.		
(1) Sector is part of a gear.		
c. Steering wheel is turned, worm is rotated causing the sector and cross shaft to turn.		

OUTLINE OF INSTRUCTION	INSTRUCTOR ACTIVITY	STUDENT ACTIVITY
2. Worm and roller.		
a. Similar to worm and sector.		
b. Worm on lower end of steering shaft has an hour glass shape.	II.E.2.b. Pass out steering gear to students.	
(1) Tapered from both ends to the center.		
(2) Gives better contact between the worm and roller at all positions.		
(3) Provides variable steering gear ratio.		
c. Roller is supported on ball or roller bearing within the sector mounted on the cross shaft.		
(1) Bearing reduces friction.		
d. Worm turns under control of steering wheel, roller turns with it but forces the sector and cross shaft to rotate.		
3. Recirculating ball and nut.	II.E.3. Have class refer to TM9-8000, pages 405, 406 and 407 to refer to illustrations of worm and sector steering gear assembly.	II.E.3. Refer to pages of text as directed by instructor and follow discussion.
a. Worm on lower end of steering shaft.		
b. Cross shaft has a sector gear.		
c. Ball nut is grooved and mounted on a continuous row of balls between the nut and worm.		

(1) Nut is fitted with tubular ball guides diagonally across the nut to recirculate the balls as the nut moves up and down on the worm.

(2) Bottom of nut has gear teeth engaged with sector.

d. When worm is turned, the nut is moved on the worm by rolling instead of sliding.

e. Turning the worm moves the nut and forces the sector and cross shaft to turn.

4. Cam and lever.

a. Worm on lower end of steering shaft is known as a cam.

b. Lever carries a tapered stud which engages with the cam.

(1) Studs may be integral or mounted on roller bearing to reduce friction.

(2) There may be one or two studs.

c. Steering wheel is turned, stud moves up and down on the cam and carries the lever with it to rotate the cross shaft.

d. Used on most military 6 x 6 trucks.

OUTLINE OF INSTRUCTION	INSTRUCTOR ACTIVITY	STUDENT ACTIVITY
F. Steering system troubles.		
1. Steering gear and linkage.		
a. Steering gear improperly adjusted.		
b. Loose steering linkage caused by wear.		
c. Bent steering linkage.		
d. Lack of lubrication.	II.F.1.d. Relate experience toward troubleshooting steering units.	II.F.1.d. Students participate in instructors guidance of related experience.
(1) Most common problem.		
(2) Always use lubricant specified by manufacturer.		
(3) Check lubricant during P.M. inspection.		
e. Worn cross shaft bushings, or bearings.		
f. Loose mounting bolts.		
2. Trouble related to the steering system is caused by:		
a. Worn steering knuckle bushings.		
b. Wheels out of alignment.		
(1) Indicated by improper tire wear.		

OUTLINE OF INSTRUCTION	INSTRUCTOR ACTIVITY	STUDENT ACTIVITY
c. Weak springs or shock absorbers.		
d. Vehicle excessively or improperly loaded.		
G. Steering system adjustments.	II.G. Provide students with job sheets on steering system adjustments.	II.G. Students refer to job sheets and take notes
1. Steering gear (bench adjustment).		
a. Worm bearing preload (worm bearing end play).		
(1) First adjustment to be made in steering assembly.		
(a) The preloading of the bearings supporting the worm shaft in the steering gear housing.		
(2) Adjusted by:		
(a) Shims.		
(b) Threaded cups or plugs.		
(3) Checked with:		
(a) Spring scale.		
(b) Inch pound torque wrench.		
b. Backlash.		
(1) The clearance between worm and the sector (or roller or lever studs).		

OUTLINE OF INSTRUCTION | **INSTRUCTOR ACTIVITY** | **STUDENT ACTIVITY**

(2) Adjusted by:

(a) Lash adjuster or adjusting screw.

(3) Checked with:

(a) Spring scale.

(b) Inch pound torque wrench.

2. Steering system adjustments (on the vehicle).

a. The center point of steering or the straight ahead position are terms used when adjusting steering gear or checking wheel alignment.

(1) The placing of the wheels in the straight ahead position with steering gear setting in the center of travel.

(2) Found by turning the steering wheel in one direction as far as it will go, and then in the opposite direction as far as it will go, counting the number of turns. Next turn the wheel back exactly halfway.

II.G.2.a.(2) Follow instructor guidance of job sheets, observing safety precautions.

b. Worm bearing preload made first.

c. Backlash adjusting screw must be backed out.

OUTLINE OF INSTRUCTION	INSTRUCTOR ACTIVITY	STUDENT ACTIVITY
d. Disconnect steering linkage from Pitman arm.		
e. Worm bearing preload.		
(1) Turn steering wheel off center in one direction until stopped, turn back one turn.		
(2) Use torque wrench or spring scale to turn steering wheel and measure pull required to keep wheel in motion.		
(3) If not within specifications, adjust by adding or removing shims or by tightening or loosening the threaded cup or plug.		
f. Backlash.	II.G.2.f. Have students remove steering gear from chassis units and disassemble them.	II.G.2.f. Students proceed to follow job sheet and accomplish instructor assignments in a safe manner.
(1) Turn steering wheel to center position.		
(2) Turn adjusting screw to remove backlash, tighten locknut.		
(3) Use torque wrench or spring scale to turn steering wheel through center position and check the highest reading.		
(4) If not within specifications, adjust by tightening or loosening the adjusting screw.		

OUTLINE OF INSTRUCTION

H. Nomenclature of tires.

  1. Thread.

    a. A layer of rubber on the outside circumference.

  2. Breakers (undertread).

    a. Layers of rubber covered cords, similar to plies.

  3. Cushion (rubber chafer).

    a. Layers of soft heat resisting rubber between plies and breakers.

  4. Plies (carcass).

    a. Layers of rubber covered cords that incircle inner portion of carcass.

  5. Bead.

    a. The part of the tire which serves to anchor the tire to the rim.

    b. Wire hoops over which the plies and breakers are looped.

      (1) Prevents the tire from stretching.

      (2) Shaped to fit the rim.

I. Types of tires.

  1. Tube type.

INSTRUCTOR ACTIVITY

II.H. Use actual tire cutaways to explain tire nomenclature.

STUDENT ACTIVITY

II.H. Turn to chapter 19, pages 390 thru 393 and refer to illustrations.

OUTLINE OF INSTRUCTION	INSTRUCTOR ACTIVITY	STUDENT ACTIVITY
a. Must be used with a tube.		
2. Tubeless type.		
a. Rim used with this type must be sealed.		
b. Tire valve must be sealed into the rim.		
c. The tire bead is constructed to seal tightly against the rim flange.		
3. Puncture sealing type.		
a. Coating of plastic material in the inner surface.		
b. When a nail or other object is removed, internal air pressure forces the plastic material into the hole, where it hardens to seal the hole.		
4. Bias-ply, radial-ply types.	II.I.4. Have class refer to text, Automotive Mechanics, 6th edition, pages 530 thru 533. Discuss tires and tire service.	II.I.4. Refer to pages of text as directed by instructor and participate in discussion.
a. Methods of applying carcass plies.		
b. Radial tires carcass plies are applied at right angles to tire circumference.		
5. Belted type.		
a. Additional belt of cord (called the tread ply) added under tread.		

b. May be steel belted.

J. Types of treads and tire markings.

1. Standard tread.

a. Most common found of tires used on commercial vehicles.

b. Designed for satisfactory traction on highways and good surface.

c. Designed to give maximum mileage.

2. Non-directional tread.

a. Lugs at 90° to center line of tire.

b. Most common tread found on tires on military vehicles.

c. Designed to give good traction in either direction.

3. Directional tread.

a. Found mostly on rubber-mounted and off-highway construction equipment.

b. Usually found only on driving wheels as power, on steering wheels they are installed for direction.

c. Designed to give maximum traction in one direction.

4. Tire markings.

   a. Size and ply.

      (1) 8-50 - 15-4 (designation of pre 1969 industry).

         (a) 8.50 is the approximate width in inches when properly mounted on the rim and inflated, but not carrying a load.

         (b) 15 is the size of the rim or the inside diameter of the tire in inches.

         (c) 4 is the number of plies.

      (2) GR70-15B.

         (a) "G" - size factor.

            1. All passenger tire constructions having the same size factor, have identical load carrying capacity at 32 PSI.

         (b) "R" - designates radial construction.

            1. "If missing" - tire is of bias construction.

         (c) 70 - the ratio of the tire.

1. The ratio of section height to section width.

   a. As high as it is wide.

(d) 15 - rim diameter in inches.

(e) B - load range.

1. Tire manufacturers no longer designate the actual number of plys used in tire construction.

LOAD RANGE	OLD PLY RATING	MAXIMUM PRESSURE
B	4	32 PSI
C	6	36 PSI
D	8	40 PSI

b. Balance mark.

(1) Found on some larger tires.

(2) A small mark approximately 1/4" in diameter.

(3) Lightest spot of the tire.

(a) Tube valve should be placed at the spot to effect best balance.

c. Serial number.

OUTLINE OF INSTRUCTION | **INSTRUCTOR ACTIVITY** | **STUDENT ACTIVITY**

(1) Indented in the sidewall.

(2) Used for identification of the tire.

K. Types of tubes.

1. Standard tubes.

   a. Consist of one layer of rubber of synthetic material.

2. Puncture sealing tubes.

   a. Contains a coating of plastic material inside the tube. It flows into and seals a puncture hole.

3. Safety tube.

   a. Two tubes in one.

   b. One is smaller than the other and joins at the rim edge.

   c. If a puncture or blowout occurs, the outside tube loses its air, but the inside tube retains its air.

L. Types of rims.

1. Drop center.

   a. Most common type found on passenger cars and small trucks.

   b. One piece and permanently fastened to the wheel.

OUTLINE OF INSTRUCTION **INSTRUCTOR ACTIVITY** **STUDENT ACTIVITY**

c. Contains a well for easier mounting and demounting of the tire.

2. Semi drop center.

a. Shallow well for mounting and demounting.

b. Has a removable flange or side ring.

(1) Flange or side ring may be one or more pieces.

c. Most common type found on trucks.

d. Used on M715 cargo truck.

3. Divided.

a. Rim is made in two sections and the sections are bolted together.

b. Found on some military vehicles and small diameter tires that have a large number of plies such as a fork lift.

M. Tube flap.

1. A piece of rubber.

a. Placed between the rim and the tube to protect the tube.

b. Used with semi drop center and divided rims.

N. Bead clips.

1. Metal clip.

a. Used on some military vehicles to hold the tire in place when the tire goes flat.

b. Generally used in multiples of 5 to 6 equally spaced on each bead of the tire.

O. Inspection of tires, tubes and wheels.

1. Faults to look for.

a. Damaged tires, tubes and wheels.

(1) Cuts in tires.

(a) Tread surface cut.

(b) Inside breaks.

(2) Breakdown of sidewalls of tire.

(a) Curb wear.

(3) Punctured tube and/or tire.

(a) Inflate tube and submerge in water watching for air bubbles.

(b) Run hand around inside of tire carefully feeling for foreign objects.

(c) Visually inspect tire for foreign objects stuck into tire that may work to inside later.

(4) Wheels.

(a) Insure lug bolt holes are not elongated.

(b) Inspect for cracks or breaks.

(c) Inspect for wheel run out.

(d) Inspect for dented rims.

1. Caused by hitting objects.

b. Unusual wear.

(1) Under inflation causes wear on both shoulders of tread.

(a) May be caused by slow leak at valve core. Always keep valve cap over core to keep dirt out.

(2) Over inflation causes center of tread wear.

(3) Mismatching.

(a) Duals side by side.

OUTLINE OF INSTRUCTION	INSTRUCTOR ACTIVITY	STUDENT ACTIVITY
1. Largest tire carries all load.		
(b) Tires on one axle larger than tires on other axles will wear rapidly to the size of smaller tires.		
(4) Worn out.		
(a) Should be replaced when approximately 1/16" tread is left.		
P. Demounting, repairing and mounting tires and tubes.		
1. Procedures.	II.P.1. Demonstrate the removal of a tire from a wheel or rim; remove and check/repair/replace; the tube; mount tire on rim or wheel, inflate to correct pressure and inspect.	II.P.1. Observe demonstration of tire service
a. Demounting.	II.P.1.a. Supervise student practice in tire service.	II.P.1.a. Practice tire service.
(1) Drop center and safety drop center rims.		
(a) Deflate.		
(b) Force the beads of the tire into the well.		
(c) Use tire tool and lift tire over the rim opposite the point where tire is forced into the well.		

OUTLINE OF INSTRUCTION

(d) Some rims of these types require that the tire be removed from the back side.

(2) Semi drop center rims.

(a) Deflate.

(b) Remove nuts and separate the rim.

b. Tube repair.

(1) Cold patch.

(2) Hot patch.

(3) Vulcanize - requires special shop equipment.

c. Tire repair.

(1) Small holes.

(a) Hot or cold patch inside.

(b) Plug (various types).

(2) Large holes.

(a) Vulcanize - requires special shop equipment.

(3) Breaks inside of tires.

INSTRUCTOR ACTIVITY

II.P.1.b. Supervise student practice in tube repair.

STUDENT ACTIVITY

II.P.1.b. Practice tube repair.

OUTLINE OF INSTRUCTION	INSTRUCTOR ACTIVITY	STUDENT ACTIVITY
(a) Boots (temporary use).		
(4) Tread.		
(a) May be recapped if wear has not exposed breakers and carcass of tire is sound.		
d. Mounting.	II.P.1.d. Supervise student practice in mounting of tires.	II.P.1.d. Practice mounting tires.
(1) Drop center and safety drop center rims.		
(a) Force beads of tire into well of wheel.		
(b) Use tire tool and/or tire mallet to force tire onto rim opposite the point where tire is forced into well of wheel.		
(c) Inflate to seat beads of tire against rim of wheel.		
(d) Deflate.		
1. To allow tube to relax removing any wrinkles or creases.		
(e) Inflate to recommended air pressure.		
(2) Semi drop center rims.		

OUTLINE OF INSTRUCTION	INSTRUCTOR ACTIVITY	STUDENT ACTIVITY

(a) Install tire on wheel.

(b) Install removeable flange.

(c) Inflate (observing safety precautions) to seat beads of tire against rim of wheel.

(d) Deflate.

1. To allow tube to relax removing any wrinkles or creases.

(e) Inflate to recommended air pressure.

(3) Safety practices.

(a) Use safety stands under vehicles.

(b) Be sure tures are deflated before disassembly.

(c) Use care in handling heavy tires.

(d) Use the proper tools.

(e) Use care in removing and replacing side rings.

NOTE: Use a safety shield or tire gauge when inflating.

(f) Make sure side rings are seated after inflating.

OUTLINE OF INSTRUCTION	INSTRUCTOR ACTIVITY	STUDENT ACTIVITY

(4) Maintenance.

(a) Check pressure daily.

1. When cool.
2. Do not bleed a tire.
3. Always use a gauge to check tires.
4. Check valve core for leaks.

(b) When front tires show unusual wear.

1. Make repairs to correct cause of wear.
2. Rotate tires using manufacturer's recommendations.

Q. Purpose of wheel balance.

1. Easier steering.
2. Prevents rough riding.
3. Prevents tire wear.
4. Methods of wheel balance.

a. Static balance.

(1) Heavy spot on the tire or wheel assembly, when raised off the ground, heaviest section will rotate to the bottom.

OUTLINE OF INSTRUCTION	INSTRUCTOR ACTIVITY	STUDENT ACTIVITY
(2) Most likely cause the wheel to bounce.		
(3) Static unbalance lies in the plane of wheel rotation.		
b. Dynamic balance.	II.Q.4.b. Explain safety operations of dynamic balance and issue job sheet on wheel balancing equipment.	II.Q.4.b. Students observe safety precautions and take notes.
(1) Heavy spot on one side of the tire.		
(2) Most likely cause the wheel to wobble or run out.		
(3) Dynamic unbalance lies in the zone on either or both sides of the plane of wheel rotation.		
III. Application.		
A. While working as members of a two (2) man team, service the steering system, tires, tubes, and wheels of the M715 1 1/4 Ton Cargo Truck. All tasks to conform to manufacturer's specifications as specified in the job sheet CM "A" JS 3.1.1.1, "Servicing the Power Train of the M715 1 1/4 Ton Cargo Truck".	III.A. Direct, supervise and evaluate student performance in servicing steering system and tires of M715 1 1/4 Ton Cargo Truck.	III.A. Service steering system and tires of M715 1 1/4 Ton Cargo Truck in accordance with manufacturer's specifications and procedures on the job sheet.
IV. Summary.	IV. Recap high points of lesson by asking oral questions on main points of lesson.	IV. Answer questions as called on by instructor.
A. Frames.		
B. Springs.		
C. Shock absorbers.		

OUTLINE OF INSTRUCTION	**INSTRUCTOR ACTIVITY**	**STUDENT ACTIVITY**
D. Steering units.		
E. Types of steering gear assemblies.		
F. Steering system troubles.		
G. Steering system adjustments.		
H. Nomenclature of tires.		
I. Types of tires.		
J. Types of treads and tire markings.		
K. Types of tubes.		
L. Types of rims.		
M. Tube flap.		
N. Bead clips.		
O. Inspection of tires, tubes and wheels.		
P. Dismounting, repairing, and mounting tires and tubes.		
Q. Purpose of wheel balance.		
V. Test:		
A. Test items from this topic will appear in the end of unit written test.		
VI. Assignment.		
A. Read Automotive Mechanics, 6th edition, pages 390-414, 423-427 and 452-465.	VI.A. Write assignment on chalkboard.	VI.A. Copy and carry out assignment.

NAVAL CONSTRUCTION TRAINING CENTER
PORT HUENEME, CALIFORNIA 93043
CONSTRUCTION MECHANIC "A" SCHOOL TRAINING COURSE A-610-0022

Classification: Unclassified

Topic: Automotive Power Train Service

Average Time: 6 Periods (Class), 29 Periods (Pract)

Instructional Materials:

A. Texts:

1. Automotive Mechanics, 6th edition, McGraw-Hill Book Co., pages 390-414, 423-427 and 452-465.
2. Organizational Direct Support and General Support Maintenance for Model M715 1 1/4 Ton 4 x 4 Cargo Truck, TM9-2320-244-24, pages 65-69, 133-152 and 179-181.
3. Organizational Direct Support and General Support, Repair Parts and Special Tools List for Truck, Cargo, 1 1/4 Ton, 4 x 4 M715, TM9-2320-244-24P, pages 20, 52-58 and 68.
4. Fluid Power, NAVPERS 16193-A, pages 1-187.
5. TM9-8000, parts 4 and 5.

B. References: None.

Terminal Objective: Upon completion of this unit each student, while working as a member of a two (2) man team, will be able to service automotive chassis and power train components using appropriate handtools, special tools, shop equipment and materials. Specifically, he will service suspension system, power train and brake system, of the M715 1 1/4 ton cargo truck. All tasks will conform to manufacturer's specifications, without error, as specified in the job sheet CM "A" JS 3.I.1.1, "Servicing the Power Train of the M715, 1 1/4 Ton Cargo Truck".

Enabling Objectives: Upon completion of this topic each student, while working as a member of a two (2) man team, will be able to service power train components using handtools, special tools, shop equipment and materials. These tasks will consist of service to clutch, transmission, drive shafts, and drive axles of the M715, 1 1/4 Ton Cargo Truck. All performance will conform to manufacturer's specifications, without error, as specified in Job Sheet CM "A" JS 3.1.1.1, "Servicing the Power Train of the M715 1 1/4 Ton Cargo Truck".

Criterion Test: While working as a member of a two (2) man team, service power train components consisting of clutch, transmission, drive shafts, drive axles, and lubrication service; using handtools, special tools, shop equipment and materials. All performance will conform to manufacturer's specifications without error as specified in job sheet.

C. Tools, Equipment and Materials:

1. Tools.

a. Automotive shop handtools.

b. Shop equipment.

2. Equipment.

a. Major.

(1) M715 1 1/4 Ton Cargo Trucks (12 each).

3. Materials (consumable).

a. Cleaning solvent.

b. Gear oil.

c. Gasoline.

d. Wiping rags.

e. Equipment repair orders.

D. Training Aids and Devices:

1. Film.

a. MA1672Q, "Automotive Troubleshooting the Clutch" (obsolete).

b. MA8070, "Planetary Gears, Principles of Operation, Part I", single sets (18 min.).

Homework: Read:

1. Automotive Mechanics, 6th edition, McGraw-Hill Book Co., pages 390-415, 423-428, and 452-466.

2. Principles of Automotive Vehicles, TM9-8000, chapters 14, 15, 16 and 17.

c. POW-001, "Power Train" (13 min.). AIMS Instructional Media Services Inc., Hollywood, Ca. 90028.

d. MA3739, "Automotive Gears, Principles of Operation" (Obsolete) (25 min.).

2. Transparencies (Ford Service Publications, P.O. Box 7750, Detroit, Michigan 48207).

   a. 7001, "Car and Truck Clutches, Principles of Operation".

   b. 7100, "Car, 3 speed Manual Shift Transmission and Overdrive, Principles of Operation".

   c. 4001, "Car Rear Axle, Principles of Operation".

3. Charts (Ford Service Publications, P.O. Box 7750, Detroit, Michigan 48207).

   a. 7002, "Car and Truck Clutch Diagnosis, Adjustment and Light Repair".

   b. 7203, "Truck 4 and 5 Speed Manual Transmission, Principles of Operation".

   c. 4200, "Car Rear Axle Diagnosis".

4. Locally Prepared Materials.

   a. Job Sheet.

      (1) CM "A" JS 3.1.1.1, "Servicing the Power Train of the M715 1 1/4 Ton Cargo Truck".

5. **Devices.**

   a. Manual 5 speed transmission (cutaway).

   b. Differential assembly double reduction (cutaway).

E. **Training Aids and Devices:**

1. 16mm sound movie projector.

2. Overhead projector.

OUTLINE OF INSTRUCTION	INSTRUCTOR ACTIVITY	STUDENT ACTIVITY
I. Introduction to the lesson.		
A. Establish contact.	I.A. Introduce self and topic.	
1. Name:		
2. Topic: Automotive Power Train Service		
B. Establish readiness.	I.B. Motivate student.	
1. Purpose.		
2. Assignment.		
C. Establish effect.	I.C. Bring out need and value of material being presented.	
1. Value.		
a. Pass course.		
b. Perform better on the job.		
c. Get advanced.		
d. Be a better Construction Mechanic.		
D. Overview:	I.D. State learning objectives.	
1. An understanding of basic gear theory simplifies working the automotive transmission, clutch, differential, and gear trains. The automotive power train may fail entirely or fail to function properly from various causes, such as wear, both normal and unusual, inadequate lubrication, improper operation and breakage.	1. State information and materials necessary to guide student.	

OUTLINE OF INSTRUCTION	INSTRUCTOR ACTIVITY	STUDENT ACTIVITY
II. Presentation.		II. Students take notes and ask questions as needed.
A. Clutch assembly. 1. Function of the clutch. a. Allows operator to couple and uncouple the engine power from the transmission. b. Allows engine to take load of vehicle without jerks or stalling of engine.	II.A. Show training aids: Clutch disc, pressure plate, and release bearing.	
2. Types of automotive clutches. a. Dry single disc automotive type clutch. (1) Transmits engine power through frictional contact with two drive members (plates) and one driven member (disc). (2) Most automotive clutches are of this type. b. Types of dry single disc clutches. (1) Diaphragm spring. (2) Helical coil spring.	II.A.2. Refer class to TM9-8000, chapter 14 to view illustrations of clutch construction.	II.A.2. Refer to TM9-8000, chapter 14 as directed.
3. Parts, nomenclature, and operation of automotive clutch.		

OUTLINE OF INSTRUCTION	INSTRUCTOR ACTIVITY	STUDENT ACTIVITY
a. Flywheel.		
(1) Coupled to engine crankshaft.		
(2) Furnishes one driving surface.		
(3) Contains clutch shaft pilot bearing.		
(a) Located in center of flywheel.		
(b) Supports forward end of clutch shaft.		
b. Clutch driven disc assembly.	II.A.3.b. Display various types of clutches. Pass on to students the actual clutch components.	II.A.3.b. Examine clutch components.
(1) Driven member of clutch.		
(2) Furnishes two driven surfaces.		
(3) Secured to clutch shaft by splines.		
(4) Must be free to move back and forth on clutch shaft.		
(5) Parts of driven assembly.	II.A.3.b.(5) Show transparencies, discuss parts and function.	II.A.3.b.(5) Take notes as needed.
(a) Hub.		
1. Splined to fit splined clutch shaft.		
(b) Torsional springs.		
1. Absorbs torsional vibrations of engine.		

OUTLINE OF INSTRUCTION	INSTRUCTOR ACTIVITY	STUDENT ACTIVITY
(c) Disc plate.		
1. Waved or curved.		
(d) Facing or lining.		
1. Riveted to disc plate.		
2. Pressed or woven asbestos compound.		
c. Pressure plate assembly.		
(1) Applies pressure for engaging of clutch.		
(2) Provides means of releasing clutch.		
(3) Parts of pressure plate assembly.	II.A.3.c.(3) Show transparencies, discuss parts and function.	II.A.3.c.(3) Follow presentation and take notes.
(a) Pressure plate.		
1. Furnishes one driving surface.		
2. Allowed to move back and forth to:		
a. Disengage clutch.		
b. Apply pressure to driven disc.		
3. Held in cover by lugs or dogs.		
a. Must turn with cover.		

OUTLINE OF INSTRUCTION | **INSTRUCTOR ACTIVITY** | **STUDENT ACTIVITY**

4. Pressure springs apply pressure to this plate.

(b) Pressure springs.

1. Apply pressure for engaging and holding the clutch engaged.

2. Located between clutch cover and pressure plate.

3. Types of springs.

   a. Diaphragm.

   b. Helical.

(c) Release mechanism.

1. Are actuated by release bearing.

2. Types of releasing mechanisms.

   a. Release levers are used on the helical spring clutch.

   b. Diaphragm spring is used on the diaphragm spring clutch.

OUTLINE OF INSTRUCTION	INSTRUCTOR ACTIVITY	STUDENT ACTIVITY
(d) Clutch cover. 1. Encloses pressure plate, pressure springs, retracting springs, and releasing mechanism. 2. Bolted directly to flywheel.	II.A.3.c.(3)(d) Display clutch assembly.	
(e) Release bearing. 1. It actuates release levers for disengaging of clutch. 2. Located on clutch shaft. 3. Operated by linkage from clutch pedal. 4. Usually a sealed prepacked ball thrust bearing.	II.A.3.c.(3)(e) Discuss parts and function.	
(f) Clutch pedal and linkage. 1. Actuates release bearing for releasing clutch. 2. Provides adjustment for wear.	II.A.3.c.(3)(f) Have class refer to clutch illustrations in chapter 28 of Automotive Mechanics, 6th edition.	II.A.3.c.(3)(f) Refer to text as directed and follow discussion.

OUTLINE OF INSTRUCTION | **INSTRUCTOR ACTIVITY** | **STUDENT ACTIVITY**

a. Adjustment known as clutch pedal free travel.

b. Amount of free travel on clutch approximately 1/2 to 1 inch.

d. Operation when disengaging clutch.

(1) Move release bearing in.

(a) By force applied to pedal and transmitted by linkage.

(2) Pressure plate moves away from clutch driven disc.

(a) By action of the release mechanism.

(3) Clutch driven disc moves away from flywheel.

(4) Clutch driven disc stops rotating.

(a) No force exerted on it.

(5) Clutch is in disengaged position.

e. Operation when engaging clutch.

(1) Release bearing moves back on clutch shaft.

OUTLINE OF INSTRUCTION	INSTRUCTOR ACTIVITY	STUDENT ACTIVITY
(a) By releasing force exerted on pedal linkage.		
(2) Pressure plate moves toward clutch driven disc.		
(a) By force of pressure springs.		
(3) Clutch driven disc starts to rotate.		
(a) By force being exerted on both sides.		
(4) Clutch is fully engaged.		
(a) When released bearing is completely away from release levers.		
f. Importance of clutch pedal free travel.	II.A.3.f. Use transparencies to show how clutch pedal free travel diminishes as clutch surfaces wear.	II.A.3.f. Follow presentation and take notes.
(1) As clutch surfaces wear, the free pedal clearance diminishes until finally the clutch cannot fully engage.		
(a) If clutch cannot fully engage, slippage will occur, causing overheating and rapid wear.		

(2) Routine checks and/or adjustment of free pedal clearance is necessary to insure full engagement of clutch.

4. Diagnosis of clutch trouble.

a. Clutch slips while engaged.

(1) Improper linkage adjustment.

(2) Broken or weak pressure springs.

(3) Worn friction facings.

(4) Grease or oil on facings.

(5) Release mechanism binding.

b. Clutch grabbing while engaging.

(1) Oil or gum on friction facings.

(2) Cracked or broken facings.

(3) Loose engine mountings.

(4) Loose transmission mountings.

(5) Loose rear spring clips or shackles.

(6) Broken torsional springs.

c. Clutch dragging while disengaged.

(1) Oil or grease on facings.

OUTLINE OF INSTRUCTION	INSTRUCTOR ACTIVITY	STUDENT ACTIVITY
(2) Warped driven disc or pressure plate.		
(3) Excessive pedal free travel.		
(4) Clutch driven disc hub bindings.		
(5) Faulty clutch pilot bearing.		
d. Clutch noises.		
(1) Hub loose on shaft.		
(2) Broken torsional springs.		
(3) Weak retracting springs.		
(4) Worn release bearings.		
(5) Excessive lug clearance.		
(6) Broken pressure springs.	II.A.4.d.(6) Show movie MA1672-Q, Automotive Troubleshooting the Clutch. Review high points of movie.	II.A.4.d.(6) View movie.
5. Clutch repair procedure.	II.A.5. Take class to shop, assign vehicles, tool cabinets and issue job sheets.	
a. Removal.		
(1) By removing engine.		
(2) By removing transmission.		

OUTLINE OF INSTRUCTION	INSTRUCTOR ACTIVITY	STUDENT ACTIVITY
(3) Clutch removal varies, according to manufacturer of the vehicle.		
(4) Due to the weight of the transmission or engine use the proper weight lifting tools.		
(5) Loosen mounting bolts evenly to relieve spring pressure.		
b. Inspection and repair.		
(1) All parts of the clutch assembly must be checked for wear, excessive heat, (heat checks) and warpage.		
c. Installation.		
(1) Be sure driven disc is installed properly.		
(2) Use a pilot or clutch shaft to align driven disc.		
6. Clutch maintenance.	II.A.6. Direct, supervise and evaluate student teams in performance of clutch service.	II.A.6. Perform clutch service in accordance with manufacturer's specifications as stated in the job sheet CM "A" JS 3.1.1.1.
a. Lubrication.		
(1) Release bearing (some types).		
(2) Linkage.		
b. Adjustments.		
(1) Clutch pedal free travel.		

OUTLINE OF INSTRUCTION	INSTRUCTOR ACTIVITY	STUDENT ACTIVITY
(a) Adjust by adjustment on linkage.		
(2) Release levers.		
(a) Major adjustment.		
(b) Should not have to be adjusted unless pressure plate needs to be closer to clutch driven disc.		
B. Gears and gear trains.	II.B. Display gear sets.	II.B. Students take notes and ask questions as needed.
1. Gear ratio and torque.		
a. Determined by the relative speed of rotation between two meshing gears.	II.B.1.a. Refer class to chapter 13 of TM9-8000 and chapter 30 of Automotive Mechanics, 6th edition.	II.B.1.a. Refer to text as directed by instructor and follow discussion.
b. Determined by the number of teeth of the driving and driven gear.		
(1) In gear systems, speed reduction means torque increase.		
c. Smaller gear with half as many teeth driving a larger gear.		
(1) Gear ratio is 2:1.		
(a) Also called mechanical advantage.		
(2) Torque ratio is 1:2.		
2. Uses of gearing, gear trains.		

OUTLINE OF INSTRUCTION	INSTRUCTOR ACTIVITY	STUDENT ACTIVITY
a. Simple gear train.		
(1) One drive gear and one driven gear.		
b. Compound gear train.		
(1) A gear train with two or more drive gears and two or more driven gears.		
c. Idler gears.		
(1) Used to change direction of drive.		
(2) Take up space between drive and driven gear.		
(3) Does NOT change ratio of drive to driven gear.		
d. Simple gear train.	II.B.2.d. Demonstrate simple and compound gear trains using chalkboard.	II.B.2.d. Follow demonstration and take notes.
(1) Count the teeth, divide the number of teeth on the driven gear by the number of teeth on the driver.		
(a) Driving gear - 20 teeth.		
(b) Driven gear - 40 teeth.		
(c) 40 divided by 20 equals 2 to 1.		

OUTLINE OF INSTRUCTION | **INSTRUCTOR ACTIVITY** | **STUDENT ACTIVITY**

(2) Measure the diameter (pitch diameter).

(a) Driving gear - 5 inches.

(b) Driven gear - 10 inches.

(c) 10 divided by 5 equals 2 to 1.

(3) Count and compare the number of revolutions each shaft makes (enclosed gear boxes).

(a) Driving shaft - 100 RPM.

(b) Driven shaft - 200 RPM.

e. Compound gear trains.

(1) Count the teeth, divide the product of all the driven gears by the product of the drive gears.

(a) Driving gears - 10 teeth, 5 teeth and 20 teeth.

(b) Driven gears - 20 teeth, 10 teeth and 40 teeth.

(c) $\frac{20 \times 10 \times 40}{10 \times 5 \times 20} = \frac{8000}{1000} = 8$ to 1.

(d) The product of all the ratios.

OUTLINE OF INSTRUCTION	INSTRUCTOR ACTIVITY	STUDENT ACTIVITY
(2) Gear ratios are always stated with the driving gear first.		
(3) Gear ratios are usually stated by the number of turns of the drive gear to one revolution of the driven gear.		
3. Gear construction, types and uses.		
a. Gear construction and nomenclature.	II.B.3.a. Use transparencies and discuss parts and function.	II.B.3.a. Students take notes.
(1) The gear is a series of levers.		
(2) Gear teeth are levers.		
(3) Shaft is fulcrum.		
(4) Can be used to increase speed or torque.		
b. Types of gears.		
(1) Spur gear.		
(a) Straight cut teeth.		
(b) One tooth of each gear in contact.		
(c) Jerky motion.		
(2) Helical gear.	II.B.3.b.(2) Show right and left hand helical gears and point out method of determining right from left.	
(a) Teeth cut on angle.		

OUTLINE OF INSTRUCTION **INSTRUCTOR ACTIVITY** **STUDENT ACTIVITY**

(b) Several teeth in contact.

(c) Smooth motion, quiet operation.

(d) Produces large amount of thrust.

(e) A right hand helical gear must mesh with a left hand helical.

(f) Determining right hand helical from left hand helical.

1. Looking at hub of gear if teeth go off to right, its a right hand helical.

2. If teeth go off to left, gear is left hand helical.

(3) Herringbone gears.

(a) Two sets of helical teeth opposing each other.

(b) Thrust is equalized.

(c) Same advantages as helical gears.

OUTLINE OF INSTRUCTION	INSTRUCTOR ACTIVITY	STUDENT ACTIVITY
(4) Worm and spur gear.	II.B.3.b.(4) Use transparencies, discuss parts and function.	II.B.3.b.(4) Take notes.
(a) Spur gear driven by a screw or worm.		
(b) Allows large mechanical advantage.		
(c) Allows torque to flow at right angle to drive.		
(d) Worm can be single or multiple threaded.		
(5) Internal gear.		
(a) Driver and driven gear turn same direction.		
(b) Allows large reduction in small space by bringing shafts closer together.		
(6) Rack and Pinion - changes rotary motion to linear motion and vice versa.		
(7) Bevel gears.		
(a) Teeth cut around the gear face.		
(b) Torque flows at right angle to drive.		

OUTLINE OF INSTRUCTION	INSTRUCTOR ACTIVITY	STUDENT ACTIVITY
(c) Types of bevel gears.	II.B.3.b.(7)(c) Introduce and show movies MA3739, "Automotive Gears, Principles of Operation" and MA8070, "Planetary Gears, Principles of Operation".	II.B.3.b.(7)(c) View films and take notes.
1. Spur bevel - straight cut teeth.		
2. Spiral bevel - curved teeth.		
3. Hypoid - curved teeth, shafts do not intersect.		
(8) Planetary gears.	II.B.3.b.(8) Review high points of movies.	II.B.3.b.(8) Participate in discussion.
(a) Internal or ring gear.		
(b) Planet carrier and pinions.		
(c) Sun gear.		
C. Transmissions.		
1. Function.	II.C.1. Using cutaway transmission, point out to class function and arrangement of gearing.	II.C.1. Students take notes and ask questions as needed.
a. Gives neutral position.		
b. Gives selection of forward speeds for operating efficiency.		
c. Gives reverse direction.		
2. Nomenclature of parts.		
a. Gears.		
(1) Types.		

OUTLINE OF INSTRUCTION	INSTRUCTOR ACTIVITY	STUDENT ACTIVITY
(a) Spur gears.		
1. usually a sliding gear.	II.C.2.a.(1)(a)1. Refer class to TM9-8000, chapter 15 and Automotive Mechanics, 6th edition, chapter 30 - discuss gears and gear trains.	II.C.2.a.(1)(a)1. Follow discussion while referring to texts as directed by instructor.
(b) Helical gears.		
1. Usually a constant mesh gear.		
2. Splines on shaft must be angled.		
b. Bearings.		
(1) Supports transmission shafts.		
(2) Some gears are supported on the shafts on bearings in order to rotate independently of the shaft.		
(3) Generally ball or roller bearing.		
(4) Some transmissions use needle bearings.		
(a) Use care in handling.		
(5) Bushings may be used instead of bearings.		
c. Control mechanism (shifting).		
(1) Gear shift lever.		

OUTLINE OF INSTRUCTION	INSTRUCTOR ACTIVITY	STUDENT ACTIVITY
(2) Shifting rails.		
(3) Shifting forks secured to rails.		
(4) Poppet balls and springs hold rails in place.		
(5) Interlock mechanism prevents shifting more than one gear at a time.		
d. Speed selectors (moved by forks).	II.C.2.d. Show transparencies, discuss parts and function.	II.C.2.d. Take notes.
(1) Sliding gear.		
(2) Sliding collar.		
(a) Collar is splined to shaft and has either internal or external teeth to engage with a gear and lock the gear to the shaft.		
(3) Synchromesh unit.		
(a) Cone clutch.		
(b) Sliding collar.		
(c) Used to prevent damage to the transmission by synchronizing the speed of the moving parts together.		

1. Prevents clashing of the gear teeth.

e. Shafts.

(1) Clutch shaft and main drive gear.

(a) Main drive gear secured to clutch shaft.

(b) Main drive gear in constant mesh with cluster gears.

(2) Counter shaft and cluster gears.

(a) Cluster gears mounted on this shaft.

1. Gears are keyed or molded to shaft.

2. Must rotate together.

3. Rotates in opposite direction to that of engine.

(3) Transmission main shaft and gears.

(a) Separated from clutch shaft by pilot bearing.

(b) All gears are sliding, or free to rotate.

(c) Synchromesh units and sliding collars are mounted on this shaft.

(4) Reverse idler shaft and idler gears.

(a) Shaft supports idler gears.

(b) Idler gears give reverse direction.

3. Types of transmissions.

a. Sliding gear selective type.

(1) Can select any speed ratio without going through intermediate stages.

(2) All conventional automotive transmissions are of the selective type.

b. Constant mesh.

(1) A complete constant mesh transmission would have all gears on the main shaft bearing mounted on the main shaft and the mating gear on the countershaft.

c. Synchromesh transmission.

(1) Very similar to a constant mesh transmission.

OUTLINE OF INSTRUCTION	INSTRUCTOR ACTIVITY	STUDENT ACTIVITY
(a) The gears on the main shaft may be bearing mounted to the main shaft and in constant mesh with the mating gear on the counter shaft or part of the gears may be sliding gears.		
(b) The sliding collars are replaced with synchromesh units.		
4. Removal and installation procedures.	II.C.4. Introduce and show film POW-001, "Power Trains".	II.C.4. View film.
a. Will vary depending on the make and model of vehicle and transmission.		
b. Check manufacturer's repair manual for steps in removal and installation.	II.C.4.b. Review high points of movie.	II.C.4.b. Participate in discussion.
5. Inspection and overhaul.		
a. Disassembly and assembly will vary depending on the make and model of the vehicle and transmission.	II.C.5.a. Take class to shop.	
b. Check manufacturer's repair manual.	II.C.5.b. Direct, supervise and evaluate student performance in disassembling, assembling and installing transmission.	II.C.5.b. Disassemble, assemble and install transmission in accordance with manufacturer's specifications as specified in the job sheet CM "A" JS 3.1.1.1.
D. Transfer cases.		
1. Function.		
a. Enables the power to be divided or transferred to both forward and rear propeller shafts.		

OUTLINE OF INSTRUCTION	INSTRUCTOR ACTIVITY	STUDENT ACTIVITY
b. Provides a lowering of the power train to permit the forward propeller shaft to clear the engine crankcase.		
c. Essentially, a two-speed unit (low and direct).		
2. Operation, construction and nomenclature.		
a. Very similar to a transmission.		
b. Some military vehicles use sprag units for the front wheel drive.		
(1) Sprag units provide an automatic means of engaging the front wheel in drive when additional tractive effect is required.		
(2) During normal operation, only rear wheels drive.		
(3) Rear wheels lose traction and begin to slip, they turn faster than front wheels and the sprag unit engages.		
E. Power take off units.		
1. Function.	II.E.1. Show transparencies and discuss parts and functions of the power take off units.	II.E.1. Take notes.
a. Enables power to be delivered to power driven auxiliary equipment.		
b. Generally mounted on and driven from transmission.		

OUTLINE OF INSTRUCTION	INSTRUCTOR ACTIVITY	STUDENT ACTIVITY
2. Operation, construction and nomenclature.		
a. Very similar to a transmission or transfer case.		
b. May be several different designs.		
(1) Single gear, single speed.		
(2) Two gear, single speed.		
(a) Changes rotation.		
(3) Single speed forward and reverse.		
(4) Two speeds forward and one reverse.		
F. Drive lines.		
1. Function of propeller shafts and universal joints.	II.F.1. Show transparencies, discuss parts and function.	
a. Connects transmission to axle assemblies.		
b. Slip joint provides for fluctuations of the axle housing.		
c. Universal joint allows one shaft to drive another at an angle.		
2. Variable velocity universal joint.	II.F.2. Direct class to TM9-8000, chapter 16 to view illustrations of propeller shafts and universal joints.	II.F.2. Follow discussion while referring to TM9-8000 as directed.
a. Construction.		

(5) Variation of velocity cannot be eliminated but its effects can be minimized by using two universal joints.

c. Timing universal joints.

(1) Due to the speed fluctuations of the driving shaft in relation to the driven shaft, it is necessary for the universal joints to be timed.

(2) Two inner yokes must be in the same plane.

(3) Most propeller shafts are made with one wide section in the splines of the slip joint and can only go together one way.

(4) Some propeller shafts are long and use a center support bearing.

(5) Propeller shafts may be in two or more sections and may have more than two universal joints.

(a) Care must be used in the reassembly of the shafts using slip joints.

(6) Improperly assembled shafts will cause an excessive vibration.

OUTLINE OF INSTRUCTION **INSTRUCTOR ACTIVITY** **STUDENT ACTIVITY**

d. Common faults and failures.

(1) Lubrication.

(a) Lack of lubrication.

(b) Over lubrication.

(c) Do not use high pressure grease guns.

(2) Worn bearings and grease seals.

(3) Universals improperly timed.

e. Removal, repair and installation of universal joints, propeller shafts and slip joints.

(1) Disconnect at universals.

(2) Remove propeller shaft.

(3) Check for the following.

(a) Shaft for straightness.

(b) Universals for wear.

(c) Slip joint for wear.

(4) Unless there are external means provided, repack universals and slip joint with grease before reassembling.

(5) Reinstall units on vehicle making certain universals are properly timed.

3. Constant velocity.

a. Found on front axles of front wheel drive vehicles.

b. Types of constant velocity joints.

(1) Cross and yoke.

(a) Construction and nomenclature.

1. Similar to variable velocity type.

2. Driving member.

3. Driven member.

4. 4 x 4 military front wheel drive.

(2) Rzeppa.

(a) Construction and nomenclature.

1. Driving member.

a. Inner axle shaft.

b. Forked.

OUTLINE OF INSTRUCTION	INSTRUCTOR ACTIVITY	STUDENT ACTIVITY
2. Driven member.		
a. Outer axle shaft.		
b. Forked.		
3. Universal joint inner portion.		
a. Male (or spigot) joint.		
4. Universal joint outer portion.		
a. Female (or slotted) joint.		
c. Theory of operation.		
(1) The balls, yokes, or forks, which are the driving contact, move laterally as the joint rotates.		
(2) Permits the point of driving contact between the two halves of the joint to remain in a plane which besects the angle between the two shifts.		
(3) No variation in speed.		
(4) Operates efficiently up to a thirty degree angle.	II.F.3.c.(4) Direct, supervise and evaluate student teams in universal joint service.	II.F.3.c.(4) Perform universal joint service while conforming to manufacturer's specifications as stated in job sheet CM "A" JS 3.1.1.1 without deviation.

OUTLINE OF INSTRUCTION	INSTRUCTOR ACTIVITY	STUDENT ACTIVITY
G. Rear axle and differentials.	II.G. Refer class to TM9-8000 chapter 17 for illustrations showing differential construction.	II.G. Refer to text as directed and follow discussion.
1. Types of drive axles units.		
a. Live axle.		
(1) Transmits torque.		
(a) May or may not carry weight of the vehicle depending on how it is mounted in the axle housing.		
(2) Semi floating.		
(a) Carries weight of the vehicle on the outer end.		
1. Inner end of axle is splined into the differential side gear.		
2. Outer end of the axle is supported by a bearing placed between the axle shaft and housing end.		
(b) Supports side thrust.	II.G.1.a.(2)(b) Show transparencies and training aids. Discuss parts and functions.	

1. On some vehicles the end of the axle shaft is tapered to fit into a tapered hub. It is also keyed in place and held by a nut on the threaded end of the axle shaft. The brake drum is fixed to the hub. The hub contains the lug bolts for mounting the wheel.

2. On other types, the end of the axle shafts are flanged. The flange contains the lub bolts. The brake drum fits over the lug bolts, then the wheel is placed on the lug bolts.

(c) Transmits torque.

(3) Full floating.

(a) Transmits torque.

(b) Does not carry weight or support side thrust.

1. The hub of the wheel is bearing mounted on the end of the axle housing.

2. The inner end of the axle is splined to the differential side gear.

3. The outer end has a flange that is bolted to the wheel hub.

   a. By removing the nuts, the axle can be removed, without removing the wheel.

2. Differential units.

   a. Parts and nomenclature.

      (1) The final drive gears and the differential assembly may be mounted in the differential carrier housing and then the case assembly can be removed and replaced as a unit in the large opening provided in the axle housing.

      (2) The final drive gears and the differential carrier assembly may be mounted in the axle housing and removed as separate pieces.

      (3) Drive pinion.

         (a) Supported in the differential carrier or the axle housing by tapered roller bearings.

(4) Bevel gear (ring gear).

- (a) Bolted or riveted to the differential case.
- (b) Spur bevel.
- (c) Spiral bevel.
- (d) Hypoid (most common).
- (e) Worm.
- (f) Changes direction of torque from propeller shaft 90° to axle shafts.

(5) Differential case.

- (a) Supported in the differential carrier or the axle housing by tapered roller bearings.
- (b) Types and construction.
  - 1. Conventional.
  - 2. High traction.
  - 3. No-spin type.

(6) Differential pinion gears.

- (a) May be two or four.
- (b) In mesh with side gears.

(c) Mounted on pinion shaft in differential case.

(d) Free to turn on pinion shaft.

(7) Differential side gears.

(a) Two gears.

(b) Mounted in differential case.

(c) Axle shaft is splined to the side gear.

(8) Bearing.

(a) Either ball bearings or tapered roller bearings may be found in differential units, but tapered roller bearings are the most common.

(9) Thrust washers and shims.

(a) Thrust washers are found between the side gears and differential case and between the pinion gears and case.

(b) Shims are used for the adjustments of the pinion and bevel gear in some differentials.

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(10) Axle shafts.

(a) Transmits the torque from the side gears to the driving wheels.

b. Operation and function of the differential (conventional).

II.G.2.b. Use cutaway differential assembly to demonstrate operation.

(1) Straight ahead.

(a) Drive pinion drives the bevel gear (ring gear).

(b) Bevel gear secured to the differential case assembly causes the differential case assembly to turn.

(c) Differential pinions mounted on pinion shaft are carried around with the case assembly.

(d) Pinions do not rotate on pinion shaft with equal traction on both rear wheels, but apply equal torque to the two side gears so that both rear wheels rotate at the same time.

(2) Turns.

(a) When on a straight road, the bevel gear, differential pinions and the differential side gears all turn as one unit.

(b) When rounding a curve, the differential pinion gears rotate on the pinion shaft.

(c) Due to the difference in the distance around the curve, it is necessary for the inner wheel to slow down and the outer wheel to speed up.

(d) Because of the slowing down of the inner wheel, it decreases the rotation of the axle shaft and differential side gear with respect to the bevel gear and differential case.

(e) The speed of the differential case then causes the differential to rotate on their shaft and walk around the slower turning inner side gear, advancing the speed of the outer gear, causing the outer wheel to turn faster.

1. Allows the driving wheels to rotate at different speeds.

(f) Speed lost in one side gear will be gained in the other side gear.

(g) Equal power is delivered to both drive wheels, however the speeds may be unequal.

(3) Loss of traction.

(a) A fault in the conventional differential is that if one driving wheel loses traction and spins, the other wheel which has more traction remains stationary and does not drive the vehicle.

(b) The wheel which has the least traction will require less torque to turn and as a result the line of power will be to that wheel.

(c) The wheel with the most traction will stop and cause the differential pinion gears to rotate on their shaft and walk around the stationary side gear.

1. The differential pinions and side gears are conventional gears and are most commonly used. Optional equipment may be used to allow for the difference in turning of the driving wheels to be locked together in case one wheel loses traction to the ground and starts to spin or slip.

   a. High traction differential pinion and side gears.

   b. Various types of non-slip units using a jaw clutch, cone clutch or disc clutch.

c. Inspection and repairs of drive axle housing unit.

(1) Inspect for:

(a) Bent or warped housing.

(b) Cracked or broken housing.

(c) Worn or defective grease seals.

(d) Leaking gaskets.

(e) Loose axle flange nuts.

(f) Loose differential case nuts.

(g) Broken axle shafts.

(2) Repairs.

(a) Welding or replacing housing.

(b) Replace all leaking seals and gaskets.

(c) Tighten all loose nuts.

(d) Replace broken axle shafts.

d. Removal, inspection, installation and adjustment of final drive units.

(1) Remove axle shafts.

(2) Disconnect propeller shaft.

(3) Remove differential case and bevel gear from the axle housing unit.

(a) Before the bearing caps are removed, they should be marked in order to be put back in the same place.

(4) Remove the pinion shaft from the axle housing unit.

(5) Inspect all parts for wear and damage.

(6) Replace the pinion and bevel gear as a matched set.

(7) Install the pinion shaft into the axle housing unit.

(8) Install the differential case and bevel gear into the axle housing unit.

(9) Make all adjustments.

(10) Replace the axle shafts.

(11) Replace the propeller shaft.

(12) Fill to the proper level with the proper type of gear oil.

  (a) Hypoid lubricant, also known as extreme pressure lubricnant.

    1. Non-foaming type.

(13) Common faults and failures.

  (a) Improper lubrication.

  (b) Oil leaks.

OUTLINE OF INSTRUCTION	INSTRUCTOR ACTIVITY	STUDENT ACTIVITY
(c) Broken axle shafts.		
(d) Loose bolts.		
(e) Worn bearing.		
(f) Worn gears.		
(g) Improper adjustments.		
e. Adjustments to the final drive units.	II.G.2.e. Instructor demonstrate adjustments.	II.G.2.e. Participate in discussion and take notes.
(1) The drive pinion and bevel gear in most automotive drive axle assemblies are mated to each other by a lapping process at the factory in order to obtain proper contact surfaces on the gear teeth.		
(a) Must be replaced as a matched set.		
(2) Tapered roller bearings are used in most drive axle assemblies to support the drive pinion and the differential case.		
(a) Bearings must be preloaded.		
1. Placing of the bearings under a slight tension.		

(3) Adjustments must be made with great care in order to provide proper meshing of the gear teeth and bearing preload.

(4) Drive pinion bearing preload.

  (a) Preloading of the tapered roller bearings on the pinion shaft to prevent end movement of the shaft.

    1. May be done with shims or a special sleeve.

  (b) Some pinion shafts have a ball bearing on the end of the shaft to control unit.

(5) Differential bearing preload.

  (a) Preloading of the tapered roller bearing supporting the differential case in the carrier or the axle housing to prevent movement of the case and bevel gear.

    1. May be done with adjusting nuts or shims.

  (b) After preloading the bearings, use a dial indicator to check the bevel gear for run out.

OUTLINE OF INSTRUCTION | **INSTRUCTOR ACTIVITY** | **STUDENT ACTIVITY**

(6) Pinion depth.

(a) The setting of the pinion gear into the bevel gear to obtain the proper tooth contact.

1. Usually done with shims.

(b) Can be checked with pinion depth setting gauge or a tooth contact pattern test.

(7) Backlash.

II.G.2.e.(7) Encourage student questions.

(a) The clearance between the teeth of the drive pinion and bevel gear (ring gear).

1. Done by moving the bevel gear closer to or further away from the drive pinion.

2. Use a dial indicator to check backlash.

(8) Tooth contact pattern test (not an adjustment).

(a) Paint the teeth of the bevel gear with prussian blue, red lead or white lead and then rotate the pinion through the paint and observe the impression.

OUTLINE OF INSTRUCTION	INSTRUCTOR ACTIVITY	STUDENT ACTIVITY
III. Application.		
A. Each component of the power train was serviced at time coverage was given in the lesson.	III.A. Direct, supervise and evaluate student performance in servicing final drive.	III.A. Service final drive in accordance with manufacturer's specifications as specified in the job sheet CM "A" JS 3.1.1.1, without deviation.
IV. Summary.		
A. Clutch assembly.		
B. Gears and gear trains.		
C. Transmissions.		
D. Transfer cases.		
E. Power take-off units.		
F. Drive lines.		
G. Rear axles and differentials.		
V. Test:		
A. A written test will be given at the end of this unit.		

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(a) The clearance between the teeth of the drive pinion and bevel gear (ring gear).

1. Done by moving the bevel gear closer to or further away from the drive pinion.

2. Use a dial indicator to check backlash.

(8) Tooth contact pattern test (not an adjustment).

(a) Paint the teeth of the bevel gear with prussian blue, red lead or white lead and then rotate the pinion through the paint and observe the impression.

(b) The pinion or bevel gear can be moved to obtain the correct tooth contact.

(c) Correct tooth contact with driving load distributed evenly over most of the side of tooth.

(d) Heel contact - move bevel gear away from drive pinion - correct backlash by moving drive pinion in.

(e) To contact - move bevel gear away from drive pinion - correct backlash by moving drive pinion in.

(f) High and narrow contact - move drive pinion toward bevel gear - correct backlash by moving bevel gear away from drive pinion.

(g) Low and narrow contact - move drive pinion away from bevel gear - correct backlash by moving bevel gear toward drive pinion.

NOTE: Move class to shop.

OUTLINE OF INSTRUCTION	INSTRUCTOR ACTIVITY	STUDENT ACTIVITY
III. Application.		
A. Each component of the power train was serviced at time coverage was given in the lesson.	III.A. Direct, supervise and evaluate student performance in servicing final drive.	III.A. Service final drive in accordance with manufacturer's specifications as specified in the job sheet CM "A" JS 3.1.1.1, without deviation.
IV. Summary.		
A. Clutch assembly. B. Gears and gear trains. C. Transmissions. D. Transfer cases. E. Power take-off units. F. Drive lines. G. Rear axles and differentials.		
V. Test:		
A. A written test will be given at the end of this unit.		

NAVAL CONSTRUCTION TRAINING CENTER
PORT HUENEME, CALIFORNIA 93043
CONSTRUCTION MECHANIC "A" SCHOOL TRAINING COURSE A-610-0022

Classification: Unclassified

Topic: Brake System Service

Average Time: 7 Periods (Class), 20 Periods (Pract)

Instructional Material:

A. Texts:

1. Automotive Mechanics, 6th edition, McGraw-Hill Book Co., pages 506-521.

2. Fluid Power, NAVPERS 16193B, pages 37-119.

3. TM9-8000, chapter 21.

B. References: None.

C. Tools, Equipment and Materials:

1. Tools.

a. Automotive shop handtools.

b. Shop equipment.

2. Equipment:

a. Major.

(1) M715 1 1/4 Ton Cargo Truck (12 ea.).

Terminal Objective: Upon completion of this unit each student, while working as a member of a two (2) man team, will be able to service automotive chassis and power train components using appropriate handtools, special tools, shop equipment and materials. Specifically, he will service suspension system, power train and brake system of the M715 1 1/4 ton Cargo Truck. All tasks will conform to manufacturer's specifications without error, as outlined in the Job Sheet, CM "A" JS 3.1.1.1, "Servicing the Power Train of the M715 1 1/4 Ton Cargo Truck".

Enabling Objectives: Upon completion of this topic each student will be able to service hydraulic brake system, while working as a member of a two (2) man team. Using appropriate handtools, special tools, materials and shop equipment, he will replace worn hydraulic system parts and bleed and adjust the system of the M715 1 1/4 ton cargo truck. All performance will conform to manufacturer's specifications without deviation as specified in the Job Sheet CM "A" JS 3.1.1.1, "Servicing the Power Train of the M715 1 1/4 Ton Cargo Truck".

Criterion Test: Disassembly, inspect, replace worn parts; assemble and bleed a master cylinder; adjust parking and service brakes. All performance will conform to procedures outlined in job sheet without deviation.

(2) 5 Ton 6 x 6 Truck (2 each).

3. Materials (consumable).

a. Cleaning solvent.

b. Brake fluid.

c. Wiping rags.

d. Brake system parts kits.

D. Training Aids and Devices:

1. Films (Navy).

a. MN1730A, "Elementary Hydraulics, Part I, Derivation of Pascal's Law" (16 min.).

b. MN1730C, "Elementary Hydraulics, Part I, Application of Pascal's Law" (12 min.).

c. MN1730E, Elementary Hydraulics, Liquids in Motion" (13 min.).

d. OPE-010, "Operation and Maintenance, Part I, Bendix-Westinghouse Air Brakes" (Color, 24 min.).

e. OE-483, "Hydraulic Brake Systems".

2. Locally Prepared Materials:

a. Job Sheet

(1) CM "A" JS 3.1.1.1, "Servicing the Power Train of the M715 1 1/4 Ton Cargo Truck".

Homework: Read:

1. Automotive Mechanics, 6th edition, McGraw-Hill, pages 506-521.

2. Fluid Power, NAVPERS 16193B, pages 37-119.

3. TM9-8000, Principles of Automotive Vehicles, chapter 21.

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b. Problem sheet.

(1) CM "A" PS 3.1.3.1, "Brake Service".

3. Devices.

a. Air brake system (mounted on board) (mock up).

E. Training Aids Equipment:

1. 16mm sound movie projector.

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OUTLINE OF INSTRUCTION	**INSTRUCTOR ACTIVITY**	**STUDENT ACTIVITY**
I. Introduction to the lesson.		
A. Establish contact.	I.A. Introduce self and topic.	
1. Name:		
2. Topic: Brake System Service		
B. Establish readiness.	I.B. Motivate student.	
1. Purpose.		
2. Assignment.		
C. Establish effect.	I.C. Bring out need and value of material being presented.	
1. Value.		
a. Pass course.		
b. Perform better on the job.		
c. Get advanced.		
d. Be a better Construction Mechanic.		
D. Overview:	I.D. State learning objectives.	
1. The theory of hydraulics as used in simple hydraulic systems is essential in understanding the function, construction, and service of hydraulic and air brakes. In this topic we will deal with basic hydraulics and brake service.	1. State information and materials necessary to guide student.	

OUTLINE OF INSTRUCTION | **INSTRUCTOR ACTIVITY** | **STUDENT ACTIVITY**

II. Presentation.

A. Theory of hydraulics.

1. Physics of fluids.

a. Substance which changes shape easily, takes shape of container.

b. Transmits pressure.

c. Slightly compressible.

2. Transmission of forces through fluids.

a. Hydraulics.

(1) The use of liquids under controlled pressure to do work.

b. Pascal's Law.

(1) Pressure exerted on a confined liquid is transmitted undiminished in all directions, and acts with equal force on all equal areas.

(2) Shape of container in no way alters pressure relations.

3. Pressure with force.

a. Force is the exertion of energy.

b. Pressure is the amount of force exerted on a unit area.

OUTLINE OF INSTRUCTION **INSTRUCTOR ACTIVITY** **STUDENT ACTIVITY**

(1) Measured in Pounds per Square Inch (PSI).

(2) Force = pressure x area.

4. Compressibility and expansion of liquids.

   a. Liquids are incompressible.

   b. All liquids do not expand the same amount when heated.

5. Volume.

   a. Quantity of oil supplied.

      (1) Measured in gallons per minute (GPM).

   b. Displacement of a unit.

      (1) Cubic inch displacement.

6. Temperature.

   a. Dominant factor affecting physical properties of fluids.

      (1) High temperature, less resistance to flow.

7. Classes of contamination.

   a. Abrasives:

(1) Sand.

(2) Weld spatter.

(3) Machining chips.

(4) Rust.

(5) Dirt.

b. Non-abrasive:

(1) Oil oxidation.

(2) Seals.

(3) Organic material.

8. Contamination control.

a. Filters - control contamination during normal operation of hydraulic systems.

b. Proper servicing procedures.

(1) Maintain tools and work area in clean dirt free condition.

(2) Container should be used to catch spilled fluid.

(3) Clean area before disconnecting lines.

(4) Plug or cap lines immediately after disconnect.

OUTLINE OF INSTRUCTION	INSTRUCTOR ACTIVITY	STUDENT ACTIVITY
(5) Wash all parts in approved cleaning solvent.		
(6) Dry and lubricate parts before assembly.		
(7) Replace all seals and gaskets.		
(8) Connect all parts with care.		
(9) Servicing equipment should be kept clean.		
9. Types of hydraulic fluids:		
a. SAE Type A.		
(1) Low viscosity rating.		
(2) Used mostly on automatic transmissions.		
b. SAE Type C.		
(1) Used on heavy duty transmissions.		
(2) Used on equipment hydraulic control units.		
c. SAE 10 W.		
(1) May be used in place of SAE Type C fluid.		
10. Simple hydraulic systems:	II.A.10. Take class to hydraulic lab, and construct simple hydraulic system using hydraulic training board.	II.A.10 Note components making up simple hydraulic system.
a. Hydraulic jack.		

b. Hydraulic lift.

c. Hydraulic brakes.

d. Hand water pump.

e. Door stop.

f. Shock absorbers.

B. Construction and operating principles of fluid power components.

1. Reservoirs - non-pressurized and vented to the atomsphere to prevent a vacuum from being formed as the liquid level lowers.

   a. Separation of air from system.

   b. Large enough to store more than the anticipated volume of fluid that the system will require.

2. Strainers.

   a. Device used to remove large particles of foreign matter from hydraulic liquids.

   b. Must be removed frequently for cleaning.

3. Filters - most common device in hydraulic systems to prevent foreign particles and contaminating substances from remaining in the system.

4. Plumbing and hoses.
    a. Circulatory system of fluid power systems.
        (1) Pipes - classified as rigid.
        (2) Tubing - classified as semirigid.
        (3) Hoses - classified as flexible.
    b. Flexible hose - used in locations subjected to severe vibration.
    c. Types of connectors.
        (1) Threaded - low pressure fluid system.
        (2) Flanged - suitable for most pressures now in use.
        (3) Flared connectors.
            (a) Used in systems that consist of tubing.
        (4) Bite type connectors.
            (a) Eliminates tube flaring yet provides strong tube connection.

5. Accumulators - hold a volume of liquid under pressure for conversion into useful work.

OUTLINE OF INSTRUCTION | **INSTRUCTOR ACTIVITY** | **STUDENT ACTIVITY**

a. Air - operated.

(1) Separator type.

(a) Bladder or bag.

(b) Diaphragm - similar to bladder.

b. Applications.

(1) Brake bleeder tank.

6. Pump - heart of hydraulic system.

a. Device for converting mechanical energy into hydraulic energy.

b. Types of positive displacement pumps.

(1) Rotary.

(a) Gear.

(b) Lobe.

(c) Vane.

7. Pressure control measurement.

a. Pressure gauge.

(1) Indicates pressure in system in pounds per square inch.

OUTLINE OF INSTRUCTION	INSTRUCTOR ACTIVITY	STUDENT ACTIVITY
8. Directional control valves.	II.B.8. Display various type control valves and explain basic function.	
a. Poppet.		
b. Rotary spool.		
(1) Most frequently used as pilot valves.		
c. Sliding spool.		
(1) Two way.		
(2) Three way.		
(a) Operating a unit in one direction.		
(3) Four way.		
(a) Used to control cylinders, motors or other valves.		
(b) Has four ports.		
9. Actuators.	II.B.9. Display actuators on hydraulic test bench.	
a. Cylinders - device which converts fluid power to linear motion.		
(1) Ram type.		
(a) Single-acting - applies force in one direction.		
(b) Double-acting - both strokes of ram produced by pressurized fluid.		

OUTLINE OF INSTRUCTION	INSTRUCTOR ACTIVITY	STUDENT ACTIVITY
(2) Telescoping type.		
(a) Series of rams in one assembly.		
(3) Piston type.		
(a) Single-acting - apply force in both directions.		
(b) Double-acting - fluid applied to either side of piston to provide movement.		
C. Hydraulic brake system; function, construction, operation, repair and adjustment.	II.C. Display various types of master cylinders.	
1. Master cylinder, single system.	II.C.1. Pass out master cylinders for students.	II.C.1. Examine cylinders and pass on to other class members.
a. Function - converts mechanical force into hydraulic pressure.		
b. Construction.		
(1) Reservoir.		
(a) Commonly mounted on cylinder.		
(b) Holds reserve fluid.		
(c) Supplies fluid to cylinder by gravity.		
(2) Cylinder.		

OUTLINE OF INSTRUCTION **INSTRUCTOR ACTIVITY** **STUDENT ACTIVITY**

(a) Smooth polished bore.

(b) Holds movable parts for applying hydraulic force.

(3) Filler cap.

(a) Cover for reservoir.

(b) Provide opening for servicing.

(c) Provide vent for reservoir.

(4) Boot.

(a) Made of rubber.

(b) Covers end of cylinder where piston rod enters.

(c) Keeps out dirt.

(d) Is vented.

(5) Piston rod.

(a) Transmits force from pedal to piston assembly.

(b) Is not attached to piston assembly.

(6) Retainer ring.

(a) Holds piston stop in cylinder.

OUTLINE OF INSTRUCTION **INSTRUCTOR ACTIVITY** **STUDENT ACTIVITY**

(7) Piston stop.

(a) Stop piston assembly on outward travel.

(8) Piston assembly.

(a) Changes mechanical force to hydraulic force.

(b) Supports secondary cup, which prevents leakage.

(9) Primary cup.

(a) Seals pressure and fluid in cylinder.

(10) Spring.

(a) Holds primary cup against piston assembly.

(b) Returns check valve to its seat.

(c) Returns check to seat when brake line pressure drops to 10 PSI.

(11) Check valve and seat.

(a) Combination inlet and outlet valve.

(b) Held in place by piston return spring.

(c) Located in bottom of cylinder.

(d) Maintains 10 PSI on brake lines.

1. Prevents wheel cups from leaking.

2. Keeps out atmospheric pressure.

(12) Intake port.

(a) Permit fluid to enter around cutaway section of piston assembly.

(13) By-pass port or compensating port.

(a) Relieve pressure in cylinder to release.

c. Opeartion in applying brakes.

(1) Press on foot pedal.

(2) Apply force to piston in master cylinder.

(3) Primary cup closes off by-pass port.

(a) Pressure build-up in master cylinder.

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(4) Check valve moves away from seat.

(5) Pressure exerted through brake lines.

(6) Pressure acts on wheel cylinder pistons.

(7) Piston moves out pushing brake shoe against brake drum.

(8) Varying foot pressure varies braking pressure.

d. Operation in releasing brakes.

(1) Release foot pedal.

(2) Master cylinder spring pushes piston and cup past the by-pass port.

(3) Spring returns piston rapidly.

(a) Partial vacuum created in cylinder.

1. Before brake spring forces fluid from wheel cylinder.

(4) Edge of primary cup collapses

(a) Fluid over edge of cup to fill low pressure area.

OUTLINE OF INSTRUCTION

(5) Fluid returns from wheel cylinder to reservoir.

(a) Through by-pass port.

2. Dual master cylinder.

a. Same function and basic construction as the single master cylinder with the following exceptions:

(1) Reservoir.

(a) Primary and secondary resevoirs.

(2) Cylinder.

(a) Two cylinders, combined in a single dual cylinder body.

(3) Piston assembly.

(a) Primary piston.

1. Installed in the cylinder toward the rear of the master cylinder.

2. Held away from the secondary piston by the primary piston return spring.

3. Supplies hydraulic force for the front brakes.

INSTRUCTOR ACTIVITY

II.C.1.d.(5) Take class to shop and trace hydraulic brake system on typical vehicle.

STUDENT ACTIVITY

OUTLINE OF INSTRUCTION INSTRUCTOR ACTIVITY STUDENT ACTIVITY

4. Has a primary and secondary cup attached.

5. Piston rod acts directly on the primary piston.

(b) Secondary piston.

1. Installed in the cylinder toward the front of the master cylinder.

2. Held away from the end of the cylinder by the secondary piston return spring.

3. Has two secondary cups and one primary cup attached.

(c) Outlets.

1. Has two outlets for transferring fluid to the wheels.

2. Two DUCK BILL check valves for drum brakes.

3. One DUCK BILL check valve for disc brakes.

NOTE: IF A DUAL MASTER CYLINDER IS USED, A NEW SAFETY (WARNING) DEVICE HAS BEEN INSTALLED TO LET THE OPER- KNOW IF HE HAS LOST BRAKING PRESSURE IN ONE OF THE TWO SYSTEMS.

OUTLINE OF INSTRUCTION	INSTRUCTOR ACTIVITY	STUDENT ACTIVITY
(d) Pressure differential valve and switch. 1. Function - warns the operator in case of failure of one brake system. 2. Operation. a. Electrical warning switch detent pin, rides in cutaway portion of movable piston. b. Pressure equal on both sides of piston, the switch is not activated. c. Pressure loss on one side of the piston, the piston will move the side of the least pressure, activating the switch.		
3. Wheel cylinder.	II.C.3. Pass out to class wheel cylinders.	II.C.3. Examine wheel cylinders and pass on to classmate.
a. Function. (1) Converts hydraulic pressure to mechanical force.		

b. Construction.

(1) Boots.

(a) Cover ends of wheel cylinders.

(b) Keep dust out of wheel cylinders.

(2) Pistons.

(a) Change hydraulic pressure to mechanical force.

(3) Cups.

(a) Seals the cylinder.

(4) Spring.

(a) Push cups against pistons.

(b) Keep cut in upright position.

(5) Cylinder.

(a) Enclosed chamber.

(b) Holds piston, spring and cup.

(c) Provide smooth surface for piston cup to move in.

(6) Bleeder valve.

(a) Permit getting air out of system.

(7) Wheel cylinders may have single, double or step pistons and cups.

4. Backing plate.

II.C.4. Display back-plate, brake shoes and lining.

a. Functions.

(1) Base for brake shoes and wheel cylinders.

(2) Holds anchor bolts.

(a) Pivot point for brake shoe.

5. Brake shoes and linings.

a. Functions of brake shoes.

(1) Base for lining.

(2) Transmits force from wheel cylinder to drum.

(3) May be self energized.

(a) The placing of the shoes in such a position that the drum tends to drag the lining along with it. The result is wedging action between the anchor and drum.

b. Construction of brake shoes.

- (1) Formed to fit arc of drum.
- (2) Internal expanding.
- (3) Primary or forward shoe.
    - (a) First shoe in forward direction of rotation.
    - (b) Brakes using adjusting linkage between shoes.
        - 1. Self energizing.
- (4) Secondary or reverse shoe.
    - (a) Second shoe in reverse direction of rotation.
    - (b) Brakes using anchor pins between shoes.
        - 1. De-energizing in forward rotation.
        - 2. Self energizing in reverse rotation.
- (5) Function of lining.
    - (a) Provides a friction surface for the drum.
    - (b) May be bound or rivited to shoe.

6. Brake drums.

    a. Function.

        (1) Provides friction surface for lining.

    b. Construction.

        (1) Drums may be cast iron, steel or aluminum.

        (2) Steel or aluminum drum use cast iron insert for friction surface.

        (3) Cast iron provides a good friction surface and dissipates heat evenly and fast.

7. Fluid lines.

    a. Transmits fluid and pressure from master cylinder to wheel cylinders.

        (1) Steel lines and flexible hoses.

8. Repair (drum brakes).

    a. Master cylinder and wheel cylinder.

        (1) Replacing complete unit.

            (a) Adjust push rod pedal liikage to master cylinder.

OUTLINE OF INSTRUCTION	INSTRUCTOR ACTIVITY	STUDENT ACTIVITY

1. 1/32" to 1/16" clearance between pushrod and master cylinder piston.

2. Check at pedal 1/4" to 3/4" free travel.

(b) Fill master cylinder.

1. Leave 1/4" space at the top of reservoir.

2. Use clean brake fluid.

(c) Bleed air from system.

(2) Repairing with kit.

(a) Remove faulty unit, wheel cylinder can be repaired without removing.

(b) Disassemble unit and clean parts to be re-used.

(c) Inspect cylinder bore.

1. If pitted or rusty, can be honed a maximum of .005.

(d) Dip all parts in clean brake fluid and assemble unit.

(e) Install unit on vehicle.

(f) Adjust linkage if master cylinder was removed.

(g) Fill master cylinder.

(h) Bleed air from system.

b. Brake shoes and lining.

(1) Replace.

(a) Check correct position of shoes when installing.

c. Brake drums.

(1) Replace.

9. Adjustment.

NOTE: THERE ARE MANY TYPES OF HYDRAULIC BRAKES. THEY ALL HAVE BASICALLY THE SAME PARTS. THE BIG DIFFERENCES ARE THE MANNER IN WHICH THE WHEEL CYLINDER ACTS ON THE SHOES AND THE WAY THE ANCHORS ARE ARRANGED. MANY TYPES OF WHEEL CYLINDERS ARE IN USE: (1) SINGLE CYLINDER, DOUBLE PISTON; (2) SINGLE CYLINDER, SINGLE PISTON. THERE MAY BE ONE OR MORE WHEEL CYLINDERS USED IN EACH WHEEL. ANCHORS MAY BE FIXED OR ADJUSTABLE, MAY BE SINGLE OR DOUBLE. METHOD OF ADJUSTMENT WILL VARY DEPENDING ON THE MAKE OF THE VEHICLE, THERE MAY BE ONLY ONE (1) OR TWO (2) ADJUSTMENTS.

OUTLINE OF INSTRUCTION | **INSTRUCTOR ACTIVITY** | **STUDENT ACTIVITY**

a. Minor adjustment.

(1) Compensates for lining wear.

(2) Methods of adjustment.

(a) Star-wheel adjuster between heel of shoes.

b. Major adjustment.

(1) Changes friction surface contact.

(2) Minor adjustment.

(a) Adjust eccentric anchor at top end of shoes.

(3) Major adjustment.

(a) Adjust anchor at heel end of shoes.

(4) Major adjustment is required:

(a) When fitting new shoes.

(b) When anchor pins are loose.

(c) When minor adjustment fails to give satisfactory results.

c. Bleeding hydraulic brake system.

NOTE: BRAKES MUST BE PROPERLY ADJUSTED.

OUTLINE OF INSTRUCTION	INSTRUCTOR ACTIVITY	STUDENT ACTIVITY
(1) Keep master cylinder full of fluid. (2) Build up pressure with foot pedal or by using brake bleeder tank. (3) Maintain pressure on foot pedal. (4) Open bleeder screw at wheel cylinder. (a) Start at wheel farthest from master cylinder. (5) Let fluid and air drain from bleeder screw. (a) Keep pressure on brake pedal until bleeder screw is tightened. (6) Keep repeating bleeding process. (a) Until only clean fluid comes out of bleeder screw. (7) Move to next wheel. (a) Farthest from master cylinder. (b) Repeat bleeding process.		
10. Maintenance. a. During rainy season with mud conditions.	II.C.10. Take class to shop and using student assistants demonstrate minor and major brake adjustments and bleeding procedures.	II.C.10. Observe and participate in brake service demonstration.

OUTLINE OF INSTRUCTION	INSTRUCTOR ACTIVITY	STUDENT ACTIVITY
(1) Wash under vehicle with high pressure water spray.		
(2) Remove brake backing plate when practicable.		
b. Use lubriplate type of lubricant (high temperature, water resistant grease).		
(1) Brake springs.		
(2) Brake eccentric anchor pins.		
(3) Brake pivot points.		
c. During freezing weather.		
(1) Keep drums and backing plates clean.		
(2) Do not use old brake fluid, moisture will freeze.	II.C.10.c.(2) Introduce and show movie OE-483, "Hydraulic Brake Systems".	II.C.10.c.(2) View film and take notes.
11. Caliper disc brakes.	Review high points of film.	Participate in discussion.
a. Generally two types.		
(1) Fixed caliper and floating caliper.		
(a) Fixed caliper brakes are rigidly attached to the steering knuckle, two or four pistons are used.		

OUTLINE OF INSTRUCTION	INSTRUCTOR ACTIVITY	STUDENT ACTIVITY
(b) Floating caliper brakes are free to move on a bracket which is attached to the steering knuckle, usually only one piston is used.		
b. Construction, nomenclature and operation.	II.C.11.b. Display disc brake caliper assembly.	
(1) Caliper.		
(a) Holds a piston or pistons that moves inside a cylinder, which is machined in the caliper housing.		
(b) May be one, two, or four pistons in the caliper.		
(c) Two and four piston calipers are made in two halves and are joined together by bolts that bridge the rotor.		
(d) The inner and outer housings are hydraulically connected by either an external tube or by internally drilled passages.		
(e) A square lip seal is used to prevent leakage of fluid from around the piston and to help return the brake shoes away from the rotor.		

(f) A dust boot is incorporated to seal dust from the cylinder bore.

(2) Rotor.

(a) Made of cast iron.

(b) Either of solid construction or with ventilating slots for cooling.

(c) Bolted to the rotor hub which is bearing mounted on the spindle.

(3) Rotor splash shield.

(a) Protects the inner surface of the rotor.

1. Wheel protects the outer surface.

(4) Brake shoes and lining.

(a) Provides the friction surface for the rotor.

1. Lining.

(b) Usually pre-cut to size according to make and model of automobile.

(c) Linings are of the molded design.

1. Dense, hard, compact material.

2. Low friction quality.

3. Dissipates heat easily.

(5) Shoe retainer.

(a) Holds shoe in place in the caliper.

1. May be a retainer plate, pin, clip or pocket method.

(6) Proportioning valve.

(a) Balances braking pressure between the front disc and rear drum brakes.

1. Due to the self-energizing action of the rear brakes.

(7) Metering valve.

(a) Keeps the front brakes from acting at low braking pressures.

1. 120 PSI and below.

(b) Maintains a lower pressure in the front brakes until master cylinder pressure reaches 500 PSI.

1. 500 PSI and above, full braking pressure.

12. Bleeding disc brakes.

a. Chrysler and Ford recommends pressure bleeding only.

b. Always bleed longest line first.

c. Maintain pressure bleeder at 10 - 30 PSI.

d. Centering pressure differential valve.

(1) Turn on ignition switch.

(a) Light comes on.

1. Apply pressure to system, open fitting in system that was not bled, or from system you bled first.

2. Hold fitting open until light goes out.

3. Fill master cylinder to 1/4 - 1/2 inch from top.

13. Hydraulic brake system troubles:

a. Brake pedal goes all the way down to to floorboard.

(1) Abnormal wear on linings.

(2) No fluid in reservoir.

(3) Leaks in brake system.

(4) Air in brake system.

(5) Rubber cups damaged in excessive heat.

(6) Rubber cups damaged by mineral oil, or wrong type of brake fluid.

b. Brakes drag at all wheels.

(1) By-pass port in master cylinder blocked.

(2) Mineral oil in brake system.

c. Brake drags on one wheel.

(1) Brake shoes too colse to drum.

(2) Weak or broken shoe return spring.

(3) Cylinder cup is distorted.

(4) Brake hose restricted.

(5) Drag or binding in emergency brake cable.

d. Spongy pedal action.

  (1) Brake shoes improperly adjusted.

  (2) Air in brake system.

  (3) New linings improperly fitting brake drums.

  (4) Flexible lines expand under pressure due to deterioration.

e. Excessive pedal pressure necessary to stop car.

  (1) Brake shoes improperly adjusted.

  (2) Fading due to overheated friction surfaces.

  (3) Lining glazed.

  (4) Lining making only partial contact with drum.

f. Brake action severe with only light pedal pressure.

  (1) Brake shoes improperly adjusted.

  (2) Loose brake backing plate.

  (3) Oil or fluid on linings.

  (4) Linings damaged by excessive heat.

(5) Scored brake drums.

g. Master cylinder failures.

(1) Check valve leaking.

(a) Open bleeder valve.

1. Fluid should spurt out.

(2) Piston rod too long.

(3) Piston struck in cylinder.

(a) Brakes will lock.

1. Check pedal clearance.

(4) Clogged vent.

(a) Brakes will drag.

1. Clean with wire.

(5) Clogged by-pass port.

(a) Brakes will lock.

1. Check with wire.

D. Mechanical parking brakes.

1. Internal expanding.

a. Located in the rear wheels and uses the same brake shoes as the service brakes.

OUTLINE OF INSTRUCTION	INSTRUCTOR ACTIVITY	STUDENT ACTIVITY
(1) Consists of a lever in the brake assembly connected to the parking brake lever by cables.		
(2) One cable from each rear wheel connects to a parking brake equalizer and one cable from there to brake lever.		
b. Adjustment.		
(1) Remove the slack or sag from the cables by tightening the adjusting device generally located near the equalizer.		
CAUTION!! DO NOT OVER TIGHTEN!!!		
2. External contracting.		
a. Located on the propeller shaft behind the transmission or transfer case.		
(1) Consists of drum which turns with propeller shaft.		
(2) Mounted band and applying lever.		
b. Adjustment.	II.D.2.b. Take class to shop and demonstrate parking brake adjustment on vehicle.	II.D.2.b. Observe and participate in demonstration.
(1) Adjust anchor capscrew to obtain proper clearance between drum and band at anchor.		
(2) Adjust guide bolt to obtain proper clearance between band and drum at lower half of band.		

OUTLINE OF INSTRUCTION | **INSTRUCTOR ACTIVITY** | **STUDENT ACTIVITY**

(3) Turn adjusting nut to obtain proper clearance between band and drum at upper half of drum.

(4) Adjust cable clevis to fit cable yoke.

3. Repair.

a. Repair consists of:

(1) Replacing or grinding drums.

(2) Replacing or relining shoes or bands.

(3) Replacing linkage.

(4) Replacing brake return springs.

E. Air brakes.

1. Construction and nomenclature of parts.

a. Air compressor.

(1) Delivers and maintains air pressure in the reservoir tanks.

(2) Usually driven by the engine, may be either belt or gear driven.

b. Governor.

(1) Automatically controls the air pressure being maintained in the reservoir tanks.

(2) Normal pressures.

(a) Minimum - 80-85 PSI.

(b) Maximum - 100-105 PSI.

c. Reservoir tanks.

(1) Volume supply of air.

(2) Means of trapping water.

(a) Two tanks, connected.

(3) Contains drain cocks.

d. Air pressure gauge.

(1) Shows air pressure in the reservoir tanks.

e. Low air pressure switch and buzzer.

(1) Automatically gives warning to the operator that air pressure is below safe operating pressure.

(2) Approximately 60 PSI.

f. Brake application valve.

(1) Provides the driver with an easily operated and graduated means of applying or releasing the vehicle brakes.

OUTLINE OF INSTRUCTION	INSTRUCTOR ACTIVITY	STUDENT ACTIVITY

g. Quick release valve.

(1) Speeds up the release of air pressure from the brake chambers.

h. Relay valve.

(1) Speeds up the application and release of the rear brakes on long wheel base vehicles.

i. Trailer handbrake control valve.

(1) Provides a means to operate the trailer brakes independently of the tractor.

NOTE: NOT TO BE USED FOR PARKING!!!

j. Brake chambers and rotochambers.

(1) Converts compressed air pressure energy into mechanical force movement which applies the vehicle brakes.

(2) One chamber for each wheel assembly.

(3) Contains diaphragm.

k. Slack adjusters.

(1) Serves as a lever during brake application

OUTLINE OF INSTRUCTION **INSTRUCTOR ACTIVITY** **STUDENT ACTIVITY**

(2) Provides a quick and easy method of making a minor brake adjustment.

2. Repair and service.

a. Replacement of complete assemblies.

b. Repair of the various valves and assemblies.

c. Lubrication.

(1) When valves are being repaired, internal operating parts and "O" rings are lubricated.

(a) Some oils and greases are harmful to rubber parts.

(2) Slack adjusters are lubricated on the P.M. schedule.

3. Adjustments.

a. Slack adjusters.

(1) Turn adjusting nut on slack adjuster.

(2) Adjust brakes to a minimum travel without brakes dragging.

OUTLINE OF INSTRUCTION	INSTRUCTOR ACTIVITY	STUDENT ACTIVITY
(3) Maximum travel at which the brakes must be readjusted depends on the type of brake chamber.	II.E.3.a.(3) Demonstrate operation of air brake system mock-up pointing out to class service points.	II.E.3.a.(3) Observe demonstration and take notes.
	Introduce and show film, "Operation and Maintenance, Part I, Bendix-Westinghouse Air Brakes" (coler, 24 min.).	View film and take notes.
	Review high points of movie.	Participate in discussion.
F. Air over hydraulic (Bendix-Air-Pac).	II.F. Display air-pac assembly.	
1. Construction.		
a. Air system.		
(1) Contains in most cases the following parts:		
(a) Air compressor.		
(b) Governor.		
(c) Air tanks with safety valve and drain cocks.		
(d) Air pressure gauge.		
(e) Low pressure indicator and warning device.		
(f) Hand control valve.		
(g) Stoplight switch.		

OUTLINE OF INSTRUCTION **INSTRUCTOR ACTIVITY** **STUDENT ACTIVITY**

(h) Double check valve.

(i) Lines and hoses for connecting units.

b. Hydraulic master cylinder and wheel cylinders are standard cylinders.

(1) Master cylinder supplies fluid to the wheel cylinder and the control valve of the air cylinder.

c. Hydraulic slave cylinder.

(1) Hydraulic piston.

(a) Connected to power piston by push rod and creates hydraulic pressure for brake application.

(b) Contains ball check valve to allow fluid to pass through to wheel cylinders from master cylinder.

(c) Closes when piston is moved by power piston.

(2) Residual check valve.

(a) Maintains pressure in lines and wheel cylinders.

d. Lubrication.

OUTLINE OF INSTRUCTION	INSTRUCTOR ACTIVITY	STUDENT ACTIVITY
(1) Use vacuum cylinder oil.		
(2) Brakes released.		
(3) Check specification for time.		
(4) Remove pipe plug in end of air cylinder and inject oil until oil just begins to run out.		
e. Bleeding.		
(1) Bleed screw at control valve first then at hydraulic cylinder.		
(2) Bleed rest of vehicle in normal procedure.		
III. Application.		
A. Knowledge gained by the students in this topic will be applied throughout the automotive chassis and power train service phase of the course.	III.A. Direct, supervise and evaluate student performance in servicing hydraulic brake system.	III.A. While working as a member of a two (2) man team, service hydraulic brake system.
IV. Summary.		
A. Theory of hydraulics.		
B. Construction and operating principles of fluid power components.		
C. Hydraulic brake system; function, construction, operation, repair and adjustment.		

OUTLINE OF INSTRUCTION	INSTRUCTOR ACTIVITY	STUDENT ACTIVITY
D. Mechanical parking brakes.		
E. Air brakes.		
F. Air over hydraulic (Bendix Air-Pac).		
V. Test:	V. Instructor pick-up TM9-8000 manuals.	V. Turn in TM9-8000 manuals.
A. Test items from this topic will appear in end of unit test.		
VI. Assignment.		
A. Read:	VI.A. Write assignment on chalkboard.	VI.A. Copy and carry out assignment.
1. Construction Mechanics 3 & 2, NAVPERS 10644 Series, Chapters 4 and 15.		

NAVAL CONSTRUCTION TRAINING CENTER
PORT HUENEME, CALIFORNIA 93043
CONSTRUCTION MECHANIC "A" SCHOOL TRAINING COURSE A-610-0022

Classification: Unclassified

Topic: Servicing the M715 1 1/4 Ton Cargo Truck

Average Time: 4 Period (Class), 4 Periods (Pract)

Instructional Materials:

A. Texts:

1. M715 Truck, Cargo, 1 1/4 Ton, 4 x 4 Organizational Direct/General Support Maintenance, Army Tank Automotive Command, Warren, Michigan 48090, pages 167-171.

2. Construction Mechanic 3 & 2, NAVPERS 10644 Series, chapters 4 and 15.

B. References: None.

C. Tools, Equipment and Materials:

1. Tools.

   a. Automotive shop handtools.

   b. Grease guns.

   c. Lubricating oil dispensers.

   d. Brake fluid dispensers.

   e. Battery water dispensers.

   f. Shop equipment.

Terminal Objective: Upon completion of this unit each student, while working as a member of a two (2) man team, will be able to service automotive chassis and power train components using appropriate handtools, special tools, shop equipment and materials. Specifically, he will service suspension system, power train and brake systems, of the M715 1 1/4 Ton Cargo Truck. All tasks will conform to manufacturer's specifications, without error, as specified in the job sheet CM "A" JS 3.1.1.1, "Servicing the Power Train of the M715 1 1/4 Ton Cargo Truck".

Enabling Objectives: Upon completion of this topic each student will be able to perform service procedures on the M715 1 1/4 Ton Cargo Truck. Specifically, he will locate service points, dispense appropriate lubricant, and check fluid levels, while using appropriate handtools, lubrication equipment and lubrication orders. All performance will meet manufacturer's specifications as specified in the job sheet CM "A" JS 3.1.1.1, "Servicing the Power Train of the M715 1 1/4 Ton Cargo Truck".

Criterion Test: Perform service procedures on M715 1 1/4 Ton Cargo Truck in accordance with manufacturer's specifications as specified in the job sheet.

Homework: Study: M715 Truck, Cargo, 1 1/4 Ton, 4 x 4 Organizational Direct/General Support Maintenance, pages 167-171.

Read: Construction Mechanic 3 & 2, NAVPERS 10644, chapters 4 and 15.

2. Equipment:

   a. Major.

      (1) M715 1 1/4 Ton Cargo Truck (12 each).

      (2) Portable lubrication unit (1 each).

      (3) Portable steam cleaner (1 each).

3. Materials (consumable).

   a. Cleaning solvent.

   b. Chassis grease.

   c. Gear oil.

   d. Hydraulic brake fluid.

   e. Distilled water.

   f. Wiping rags.

D. Training Aids and Devices:

1. Locally Prepared Material.

   a. Job Sheet.

      (1) CM "A" JS 3.1.1.1, "Servicing the M715 1 1/4 Ton Cargo Truck".

E. Training Aids Equipment: None.

OUTLINE OF INSTRUCTION	INSTRUCTOR ACTIVITY	STUDENT ACTIVITY
I. Introduction to the lesson.		
A. Establish contact.	I.A. Introduce self and topic.	
1. Name:		
2. Topic: Servicing the M715 1 1/4 Ton Cargo Truck.		
B. Establish readiness.	I.B. Motivate student.	
1. Purpose.		
2. Assignment.		
C. Establish effect.	I.C. Bring out need and value of material being presented.	
1. Value.		
a. Pass course.		
b. Perform better on the job.		
c. Get advanced.		
d. Be a better construction mechanic.		
D. Overview:	I.D. State learning objectives.	
1. An important element of the preventive maintenance program is the periodic performance of scheduled lubrication services. In this lesson you will learn the proper procedure for conducting P.M. checks of automotive equipment.	1. State information and materials necessary to guide student.	

OUTLINE OF INSTRUCTION **INSTRUCTOR ACTIVITY** **STUDENT ACTIVITY**

II. Presentation.

- A. Preventive maintenance (PM).
  - 1. Purpose.
    - a. Periodic performance of scheduled inspections.
      - (1) Lubrication services.
      - (2) Adjustments.
    - b. Keeps equipment in safe and serviceable condition.
    - c. Minimizes cost of maintenance.
  - 2. Operator's responsibility.
    - a. First in line of defense against equipment wear.
      - (1) Daily inspection of equipment.
        - (a) For failures and damage.
    - b. Make note of equipment defects on Operator's Inspection Guide and Trouble Report, NAVFAC 9-11240/13.
  - 3. Mechanic's responsibility.
    - a. Receives Equipment Work Order (EWO), NAVFAC 9-11200/41.

OUTLINE OF INSTRUCTION	INSTRUCTOR ACTIVITY	STUDENT ACTIVITY
(1) From his shop supervisor. (a) For interim repairs. (b) For preventative maintenance.	II.A.3.a.(1) Pass out pertinent forms for students to examine.	II.A.3.a.(1) View forms and participate in discussion.
(2) Authorization to perform work listed by inspector on EWO.		
(3) Any needed repairs observed by mechanic that are not listed by the inspector should be brought to the attention of the shop supervisor.		
(4) Mechanic initials all work performed by him and indicates time required to perform the job.		
(5) Mechanic lists parts needed on EWO and when authorized by shop supervisor, draws parts from shop stores.		
(6) Upon completion of job, mechanic returns EWO to shop supervisor for final inspection.		
NOTE: Some duty stations use a shop repair order (SRO) NAVFAC 9-11200/3A in place of the EWO.		
b. Interpretation of preventive maintenance guides.		

OUTLINE OF INSTRUCTION **INSTRUCTOR ACTIVITY** **STUDENT ACTIVITY**

(1) Speeds and aids the mechanics scheduled job.

(2) Guides for repair of safety and serviceability deficiencies.

(3) Guides for proper lubrication of equipment.

(4) Guides for scheduled services.

   (a) Type "A" - at intervals of 40 working days.

   (b) Type "B" - 2000 miles, 120 hours, or after 2 "A" PM's.

   (c) Type "C" - As directed by maintenance supervisor, oil and filter at 4000 miles, 80 days or 240h MAX.

(5) PM Service inspection record.

   (a) Adhesive-type sticker placed on equipment.

   (b) Reminder for next PM service.

   (c) Information of last oil, filter and lubrication service.

OUTLINE OF INSTRUCTION	INSTRUCTOR ACTIVITY	STUDENT ACTIVITY
B. Lubrication.	II.B. Write pertinent information on chalkboard, emphasize cleanliness in the application of lubricants.	II.B. Copy and follow discussion.
1. Theory and purpose of lubrication.		
a. Reduce friction.		
(1) Surfaces protected by film of oil.		
b. Carries heat away.		
c. Sealer.		
(1) Aids compression.		
(2) Seals working parts against oxidation.		
d. Cleans.		
(1) Suspends foreign materials.		
(a) Carbon.		
(b) Metal particles.		
2. Factors affecting lubrication.		
a. Load.		
(1) Force against oil film.		
b. Speed.		
(1) Internal friction of oil.		

c. Temperature (climatic).

(1) Viscosity.

(a) Internal resistance to flow.

(2) Govern use of:

(a) Light oils.

(b) Heavy oils.

d. Cleanliness.

(1) Weather.

(a) Dust (earth).

(b) Dust (industrial).

(c) Inside building.

(d) Water (rain).

3. Properties of lubricants.

a. Adhesion.

(1) Stick to something.

(2) Factor of use for centrifugal action.

b. Cohesion.

(1) Stick together.

OUTLINE OF INSTRUCTION **INSTRUCTOR ACTIVITY** **STUDENT ACTIVITY**

(2) Factor as a repellant.

c. Viscosity.

(1) Saybolt seconds universal.

(2) Specified amount of oil.

(3) At certain temperature.

(4) Orifice (standard) for series.

d. Four point.

(1) Lowest temperature at which an oil will flow.

e. Flash point.

(1) Temperature at which vapors will burn but will not sustain flame.

f. Fire point.

(1) Temperature at which vapors will burn.

(2) Will sustain flame.

4. Types of lubricants.

a. Oils.

(1) Classification.

(a) Mineral.

1. No detergent additives.

(b) Heavy duty.

1. Contains detergent additives.

(2) Uses.

(a) Mineral.

1. Gear boxes.

2. Some air compressors.

3. Hydraulic systems.

(b) Heavy duty.

1. Diesel engines.

2. Gasoline engines.

3. Some transmissions.

(3) Heavy-duty grade engine oils.

(a) OE-HD030.

(b) OE-HD010.

(4) Multiple-grade engine oils.

(a) 10-20-30.

(b) 20-40.

(5) Non-detergent grade oils.

(6) Rock drill oil.

  (a) SAE 30.

  (b) SAE 50.

(7) Rotary compressor oil.

  (a) 2190 Tep.

(8) Hydraulic oil.

  (a) Comply strictly with manufacturer's recommendations.

b. Gear oils.

(1) G.O. #80 - S.A.E. #80.

  (a) Transmissions below 32°F.

  (b) Differentials below 32°F.

  (c) Final drives below 32°F.

(2) G.O. #90 - S.A.E. #90.

  (a) Transmissions above 32°F.

  (b) Differentials above 32°F.

  (c) Final drives above 32°F, below 90°F.

OUTLINE OF INSTRUCTION **INSTRUCTOR ACTIVITY** **STUDENT ACTIVITY**

(3) 5190 - S.A.E. #140.

(a) Final drives above 90°F.

(b) Tractor Transmissions above 90°F.

c. Automatic transmission fluids.

(1) Use only fluid specified by the transmission manufacturer.

d. Greases.

(1) Classification and use.

(a) Grease, multi-purpose II.

1. Used for all lubrication in place of:

a. Wheel bearing (WB).

b. Chassis grease (CG).

c. Ball and roller (BR).

d. Water pump (WP).

e. Roller lubricant (RL).

(b) Water pump grease.

1. Used for lubrication of:

a. Water pump packing.

        b. Gland-type only.

    (c) Exposed gear and wire rope lubricant (CW).

        1. Sticky, thick, black residual oil.

        2. Use #2 for:

            a. Exposed gear trains.

            b. Wire rope.

5. Lubrication charts and instructions.

II.B.5. Show examples of lubrication charts, instructions, and military lube orders.

    a. Source.

        (1) Equipment manufacturer.

        (2) Naval Facilities Engineering Command.

        (3) Military Technical Manuals.

    b. Information on charts.

        (1) Type of lubricants to use.

        (2) Intervals of service.

        (3) Location of lubrication points.

        (4) Capacities.

OUTLINE OF INSTRUCTION

6. Lubrication tools and equipment.
    - a. Pneumatic equipment.
        - (1) Grease pumps.
            - (a) High pressure 40:1 to 50:1 ratio.
            - (b) Low pressure 4:1 to 6:1 ratio.
        - (2) Transfer pumps.
            - (a) Large volume.
            - (b) Transferring oils.
    - b. Hand-operated equipment.
        - (1) Push-type grease applicator.
            - (a) Low pressure.
        - (2) Lever-type grease applicator.
            - (a) High pressure.
            - (b) To 5000 PSI.
                - 1. Size of plunger.
        - (3) Volume grease applicator.
            - (a) Low pressure - high volume.
            - (b) Track roller frames.

INSTRUCTOR ACTIVITY

II.B.6. Display pneumatic lube equipment and hand-operated lube guns.

STUDENT ACTIVITY

OUTLINE OF INSTRUCTION | **INSTRUCTOR ACTIVITY** | **STUDENT ACTIVITY**

c. Types of fittings.

  (1) Hydraulic (alemite or zerk).

  (2) Button head.

d. Safety precautions.

  (1) Under lubrication.

    (a) Worn parts.

    (b) Close overhaul periods.

  (2) Over-lubrication.

    (a) Blown seals.

      1. Seals retain lubricant.

      2. Close overhaul periods.

    (b) Damage to:

      1. Clutch discs.

      2. Brakes.

II.B.6.d.(2) Emphasize fact that over-lubrication can in some instances be as detrimental as under lubrication.

  (3) Wrong type of automatic transmission fluid.

    (a) Seals will swell.

    (b) Leads to quick failure.

  (4) Clean lubrication area.

OUTLINE OF INSTRUCTION	INSTRUCTOR ACTIVITY	STUDENT ACTIVITY
(a) Slipping and falling.		
(b) Lubricants collect dirt.		
(c) Fire hazard.		
(5) Clean equipment before lubricating.		
III. Application.		
A. Knowledge gained by the student will be applied throughout the automotive chassis phases of the course.	III.A. Direct student activities in locating service points and dispensing appropriate lubricant and fluids.	III.A. Locate points on M715 1 1/4 Ton Cargo Truck and dispense appropriate lubricant and fluids according to manufacturer's specifications as specified in the job sheet.
IV. Summary.		
A. Preventive maintenance.		
B. Lubrication.	IV.B. End of phase. Pick up textbooks and tool crib keys.	
V. Test:		
A. End of unit written test.		
VI. Assignment.		
A. Study: SW 3 & 2, NAVPERS 10653-Z, pages 152-170 and 187-220 in preparation for Oxy-Mapp Gas Heating and Cutting.	VI.A. Have representative from Heavy Chassis Phase pass out texts and write assignment on chalkboard.	VI.A. Copy assignment and carry out same.

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CM "A" IS 3.1.1.1

Light Chasis

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CONSTRUCTION MECHANIC "A" SCHOOL TRAINING COURSE A-610-0022

INFORMATION SHEET

Excerpts from M715 1 1/4 Ton Cargo Truck Organizational Direct, General, Support Maintenance Manual.

TITLE: Servicing the Power Train of the M715 1 1/4 Ton Cargo Truck

INTRODUCTION: The purpose of this information sheet is to guide you in your practical performance of removing, disassembly, adjustment, repair and reassembly of the M715 Power Train Components.

This information sheet covers orderly removal and installation of all component parts and assembly of the M715 Power Train.

8-6

TRANSMISSION

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07-1. General

The four speed, cane shift, synchromesh transmission provides four speeds forward and one reverse with synchromesh engagement in second, third, and fourth speed.

07-2. Transmission Removal

a. Drain the transmission. Replace the drain plug.

b. Remove the transfer lever cover and floor board inspection cover.

c. From underside of vehicle disconnect the transfer shift rods and parking brake control cable from the lever assembly mounted on the right side of the transmission housing.

d. Remove the three bolts securing transfer lever and parking brake handle assembly to the transmission and remove lever and handle assembly.

e. On winch equipped vehicles, disconnect power take-off control rod from power-take-off mounted on the left side of the transmission.

f. On winch equipped vehicles, disconnect winch driver propeller shaft from power-take-off.

g. Disconnect and remove the intermediate propeller shaft mounted between the transmission and transfer case. To do this, loosen the transfer case mounting and move slightly back.

h. Disconnect the front axle propeller shaft from the transfer case.

i. Place jacks under the engine and transmission. Protect the engine oil pan with a block of wood placed between the jack and pan.

j. Remove bolts securing torque arm and rear motor mount to frame crossmember.

k. Remove bolts securing motor support frame crossmember to right and left frame side rail brackets and slide crossmember rearward to free member from brackets. Place crossmember on floor out of work area.

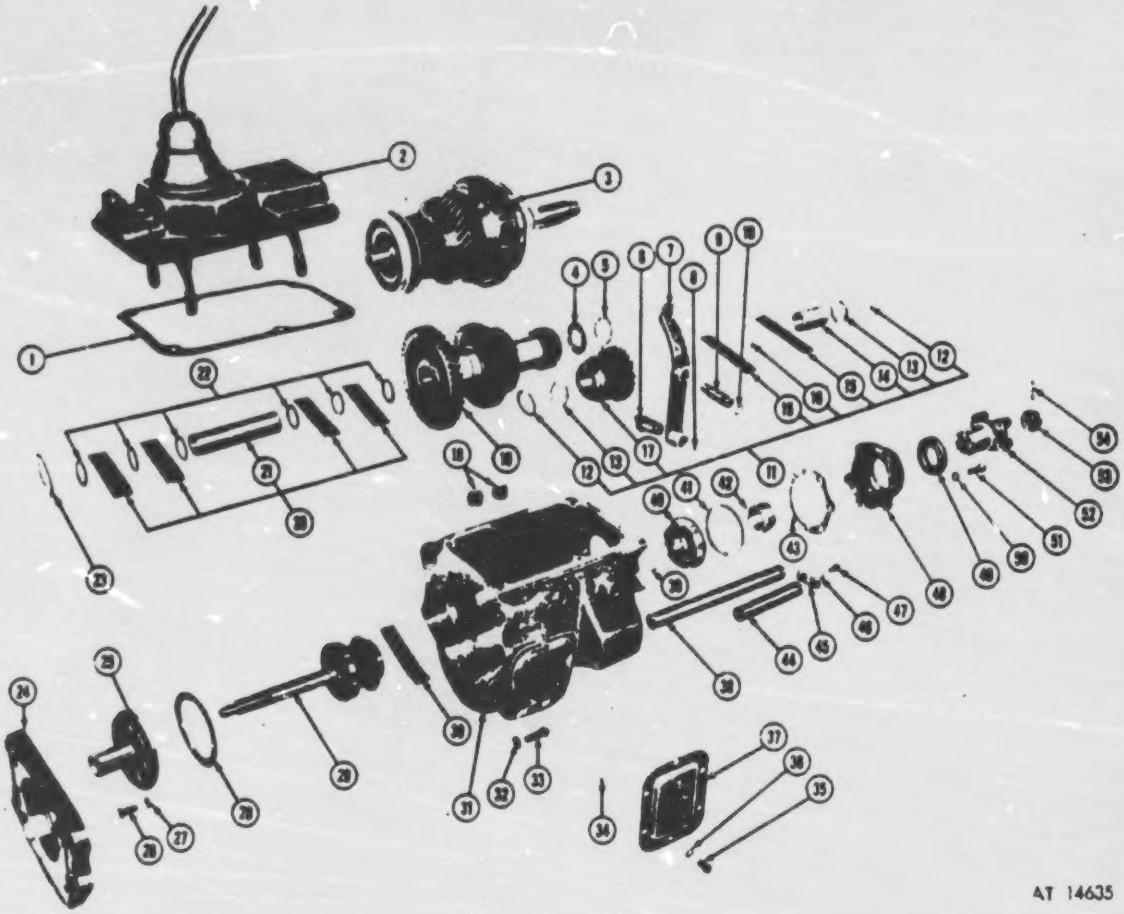
l. Remove the four bolts securing the transmission to the flywheel housing.

m. Lower engine and transmission slightly while sliding transmission rearward. When transmission main drive clears the flywheel housing tilt transmission slightly forward and lower transmission to floor. Remove transmission from under the vehicle.

07-3. Transmission Disassembly

a. Remove the bolts securing the control housing assembly to the transmission housing. Remove control housing and gasket.

b. Remove the five bolts securing the power-take-off housing to the transmission housing. Remove power-take-off housing assembly and gasket.



1	Gasket, control housing
2	Housing, control
3	Shaft, main assembly
4	Washer, countershaft thrust, rear
5	Washer, countershaft thrust, rear (steel)
6	Shoe, transmission shifting, reverse
7	Arm, transmission reverse shifting
8	Washer, "C" transmission shifting shoe, reverse
9	Pivot, transmission reverse shifting arm
10	Oil seal, transmission reverse shifting arm pivot
11	Gear, reverse idler, assembly
12	Snap ring, reverse idler gear
13	Washer, reverse idler gear thrust
14	Sleeve, reverse idler shaft
15	Roller, reverse idler gear bearing
16	Spacer, reverse idler gear bearing roller
17	Gear, reverse idler
18	Plug, pipe, 3/8"
19	Gears, transmission countershaft
20	Bearing, roller, countershaft gear
21	Spacer, countershaft bearing
22	Washer, countershaft bearing
23	Washer, countershaft thrust, front (bronze)
24	Omit
25	Retainer, main drive gear bearing
26	Bolt, hex. hd., 5/16"-18 x 7/8"
27	Lockwasher, 5/16"
28	Gasket, bearing retainer, main drive gear
29	Gear, main drive (27 teeth)
30	Roller, transmission main shaft pilot bearing
31	Case, transmission
32	Lockwasher, 9/16"
33	Bolt, hex. hd., 9/16"-12 x 1¾"
34	Gasket, transmission case side opening cover
35	Bolt, hex. hd., 3/8"-16 x 5/8"
36	Lockwasher, 3/8"
37	Cover, transmission, case side opening
38	Countershaft, transmission
39	Pin, taper, no. 0 (shifting arm pivot)
40	Bearing, transmission main shaft
41	Snap ring, main shaft bearing
42	Collar
43	Gasket
44	Shaft, reverse idler gear
45	Plate, lock, idler and countershaft
46	Lockwasher, 3/8"
47	Bolt, hex. hd., 3/8"-16 x 5/8"
48	Seal housing
49	Seal
50	Star washer
51	Capscrew
52	End yoke
53	Locknut
54	Cotter pin

Figure 07-1. Four-speed transmission.

c. Remove propeller shaft flange and transmission main shaft rear bearing retainer assembly from rear of transmission.

d. Remove the oil seal from the bearing retainer housing.

e. To make certain the two blocking rings, direct-and-third clutch hub, and the direct-and-third clutch sleeve will be reassembled in their original order, mark them with a quick-drying lacquer. Also mark the blocking ring, low-and-second clutch hub, and the low-and-second speed gear.

f. Slide the low-and-second gear toward the rear of the transmission case.

g. Disengage the reverse shifting arm from the reverse idler gear. Remove the reverse gearshift arm from the reverse shifting arm.

h. Slide the low-and-second gear back into neutral position.

i. Remove the snap rings from the main drive gear shaft and the outer race of the ball bearing.

Note. If only the main drive gear bearing is to be replaced, it can be removed with a bearing puller.

j. The oil slinger can be removed after removing the main drive gear bearing.

k. Remove the snap ring from the outer bearing race of the transmission main shaft rear ball bearing.

l. With a bearing puller, remove the mainshaft ball bearing.

m. Disengage the mainshaft assembly from the main drive gear.

n. Being careful not to lose any of the mainshaft pilot bearing rollers, lift the mainshaft assembly out through the top of the transmission case.

o. Pull the main drive gear out of the rear of the transmission case.

p. Remove the mainshaft pilot bearing rollers from the gear.

q. Remove the lock plate bolt, lockwasher, and lock plate.

r. Use a pry bar in the lock plate slot of the reverse idler gear shaft to loosen the shaft. Then slip the shaft out of the housing and gear. Lift the reverse idler gear assembly out the top of the transmission case.

s. With a heavy brass drift, drive the countershaft toward the rear of the transmission case. When the countershaft end is even with the inside of the transmission case, use a dummy shaft to force it the remainder of the way.

t. With the dummy shaft in position, place the transmission case on its side and carefully roll the countershaft gears out of the case.

u. Complete the disassembly by removing the dummy shaft, thrust washers, four sets of bearing rollers, and spacers.

v. To disassemble the reverse idler gear assembly, remove one of the snap rings and tap out the thrust washer, both sets of bearing rollers, center spacer and sleeve. Remove the remaining snap ring.

w. Remove the reverse shifting arm pivot taper pin.

x. Remove the reverse shifting arm pivot and O-ring.

07–4. Mainshaft Disassembly

a. Remove the snap ring which holds the second-speed synchronizer assembly on the mainshaft.

b. Slide the second-speed synchronizer assembly and the second-speed gear off the mainshaft. When removing the second-speed gear, be careful not to lose any of the bearing rollers.

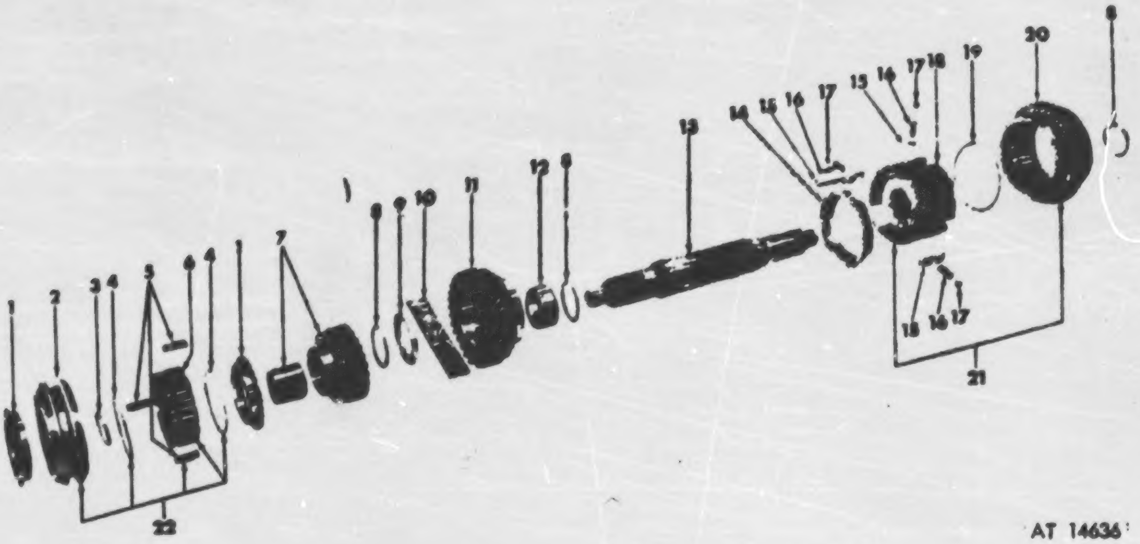
c. Remove the two remaining snap rings, spacer, and thrust washer from the mainshaft.

d. Remove the two large lockrings and push the direct-and-third clutch hub out of the sleeve.

e. If the second-speed synchronizer assembly is to be disassembled, wrap the assembly in a cloth to prevent losing the lock balls and poppet springs. Then push the low-and-second clutch hub out of the low-and-second speed gear in a direction opposite the shift fork groove. Remove the cloth and lift balls, springs, and shifting plates out of the hub.

07–5. Control Housing Disassembly

If hard shifting, simultaneous shifting into two gears, or jumping out of gear is experienced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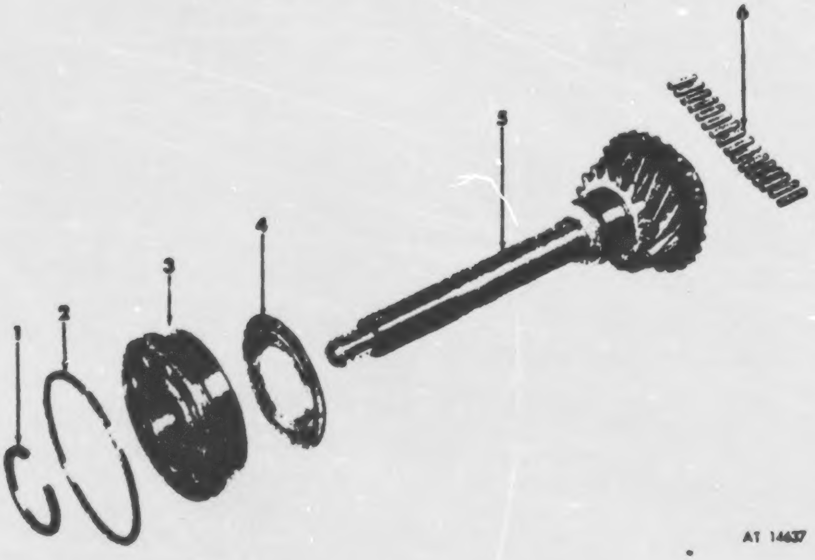
1 Blocking ring
2 Direct-and-third clutch sleeve
3 Snap ring
4 Lock ring
5 Shifting plate
6 Direct-and-third clutch hub
7 Third-speed gear assembly
8 Snap ring
9 Thrust washer
10 Bearing rollers
11 Second-speed gear
12 Spacer
13 Mainshaft
14 Blocking ring
15 Shifting plate
16 Poppet spring
17 Ball
18 Low-and-second clutch hub
19 Retaining ring
20 Low-and-second speed gear
21 Second-speed synchronizer assy.
22 Direct-and-third synchronizer assy.

Figure 07-2. Transmission mainshaft.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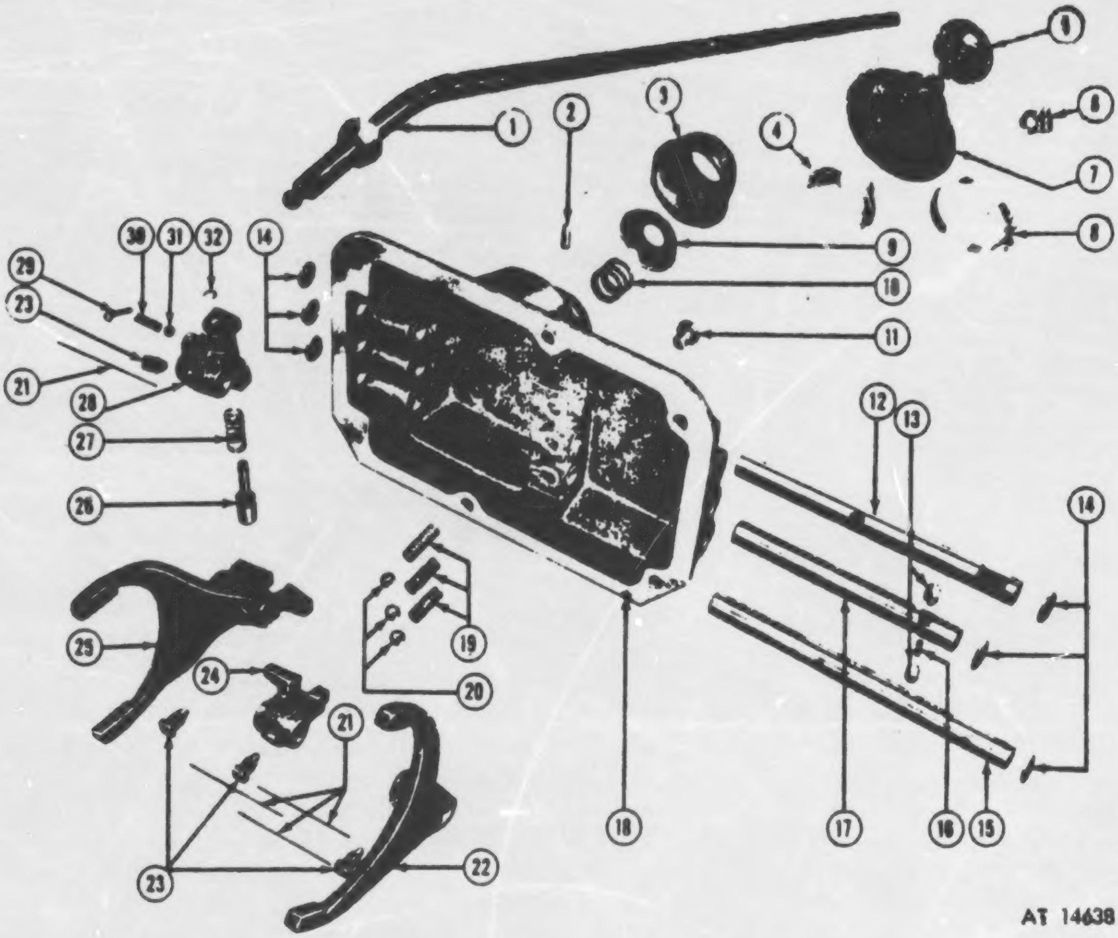
1 Snap ring
2 Snap ring
3 Bearing
4 Washer
5 Main drive gear
6 Bearing rollers

Figure 07-1. Transmission main drive gear.



1 Gearshift lever
2 Control housing pin
3 Control housing cap
4 Spherical cap
5 Shift handle knob
6 Upper boot clamp
7 Gear shift lever boot
8 Lower boot clamp
9 Washer
10 Control lever spring
11 Breather
12 Reverse shift rail
13 Shift rail interlock plunger
14 Expansion plug
15 Low-and-second shift rail
16 Shift rail interlock pin
17 Direct-and-third shift rail
18 Control housing
19 Shift rail poppet spring
20 Shift rail poppet ball
21 Lockwire
22 Low-and-second shift fork
23 Lock screw
24 Shift rail end
25 Direct-and-third shift fork
26 Reverse plunger
27 Reverse plunger spring
28 Reverse rail end
29 Cotter pin
30 Reverse plunger poppet spring
31 Reverse plunger poppet ball
32 C-washer

Figure 07-4. Control housing assembly.

with the four-speed transmission, the trouble may be in the control housing assembly (figure 07-4). The control housing can be disassembled as follows:

a. Remove the three lock wires and three lock screws from thes gearshift forks and gearshift rod ends. Remove the six expansion plugs from the front and rear of the control housing.

b. Before removing shift rails, cover the poppet ball hole to prevent loss of poppet balls and springs. The direct-and-third shift rail is to be removed first. Drive this shift rail out of the rear of the gearshift lever base. As the shift rail is withdrawn from the center section of the gearshift base, remove the shift rail interlock pin from the crossover hole in the direct-and-third shift rail.

c. Remove the low-and-second speed shift rail in the same manner.

d. Remove the shift rail poppet balls and springs. With a piece of wire, push the two shift rail interlock plungers out of the pockets in the center section of the control housing.

07–6. Reverse Shift Rail End Disassembly

The reverse shift rail end is a spring-loaded plunger which prevents accidentally shifting into reverse gear. Should this part require servicing, proceed as follows:

a. Remove the cotter pin from the reverse rail end and at the same time hold a finger over the hole to prevent loss of the reverse plunger poppet spring and ball. Then shake out the spring and ball.

b. Remove the reverse plunger. Compress the spring until the C-washer groove just clears the end of the casting. Remove the C-washer.

07–7. Rear Bearing Retainer Oil Seal

It is important that the rear bearing oil seal be correctly installed to prevent oil leakage. Correct position of the seal lip is towards the front of the transmission. Always replace the oil seal whenever it has been removed.

07–8. Transmission Assembly

Refer to figure 07–1.

07–9. Reverse Shift Rail End Assembly

Refer to figure 07–4.

a. Insert the reverse plunger spring and reverse plunger into the reverse rail end. Compress the reverse plunger until the grooved end clears the casting and secure in place with the C-washer.

b. Position the reverse plunger poppet ball and spring into the reverse rail end. Compress the ball and spring and secure with a cotter pin.

07–10. Transmission Control Housing Assembly

Refer to figure 07–4.

a. Position the two shift rail interlock plungers and interlock pin into the pocket of the center section of the control housing.

b. Install the shift rail poppet balls and springs into their respective positions in the control housing.

c. Compress the low and second speed shift rail poppet ball and spring and install the low and second speed shift fork, shift rail end and shift rail.

d. Neutralize the low and second speed shift rail so the interlock will center in the shift rail detent pocket.

e. Compress the direct and third shift rail poppet ball and spring and install the shift fork and shift rail.

f. Compress the reverse rail poppet ball and spring and position the reverse rail end assembly to the control housing. Install the reverse shift rail.

g. Align the shift forks to the shift rail lock screw holes and secure in place with the four lock screws. Secure each of the four shifter lock screws to their respective shifter fork with safety wire.

h. Position the six expansion plugs to the front and rear of the control housing and secure in place by tapping firmly on the raised portion of each expansion plug.

i. Install the gear shift lever and control housing pin into the control housing and at the same time align the lever to the shifter fork neutral groove.

j. Secure the gearshift lever and control housing pin with the control lever spring, washer and control housing cap.

k. Install gear shift handle (knob) on gear shift lever.

07–11. Mainshaft Assembly

Refer to figure 07–2.

a. Position the three shifting plates, poppe springs and balls into the recesses in the low and second clutch hub.

b. Slide the low-and-second speed gear on the low and second clutch hub, at the same time guiding the second-speed gear over the three shifting plates, poppet springs, and balls.

c. Install retaining ring at the rear of the second-speed synchronizer assembly.

d. Install the blocking ring at the front of the second-speed synchronizer assembly.

e. Install the second-speed sychronizer on the main shaft and secure in position with the 2 snap rings.

f. Lubricate and install bearing rollers, and spacer into the second-speed gear.

g. Install second-speed gear on mainshaft and center with the blocking ring. Secure in place with snap ring.

h. Position thrust washer on mainshaft and to second-speed gear.

i. Assemble third-speed gear assembly onto mainshaft.

j. Position the three shifting plates to the direct and third clutch hub.

k. Assemble the direct and third clutch sleeve on the direct and third clutch hub and over the three shift plates.

l. Install the two lock rings on to the direct and third synchronizer assembly.

m. Position both blocking rings to the direct and third synchronizer assembly.

n. Install direct and third synchronizer assembly to mainshaft and secure in place with a snap ring.

07–12. Main Drive Gear

Refer to figure 07–3.

a. Lubricate and install rollers to rear of main drive gear.

b. Assemble slinger washer bearing to main drive gear and secure with the snap ring.

Note. Outer snap ring will be installed after assembling main drive gear to transmission.

07–13. Transmission

Refer to figure 07–1.

a. Lubricate and install rollers, spacer, sleeve, thrust washer, into the reverse idler gear and secure in position with the two snap rings.

b. Position the reverse idler with the groove facing toward the front of the transmission case and install the reverse idler gear shaft with the groove for the locking plate facing "in" toward the center.

Note. Use care installing the reverse idler shaft so as not to dislodge the needle roller bearings in the reverse idler gear.

c. Install dummy shaft in counter shaft gear.

d. Lubricate and install the long spacer, four roller spacers, bearing rollers and thrust washers to the countershaft gear, using the dummy shaft as a guide.

e. Install the reverse shifting shoe in the reverse shifting arm and secure in place with the retaining C-washer.

f. Position reverse shifting arm to reverse idler groove and to the transmission case.

g. Install O-ring on reverse shifting arm pivot.

h. Install reverse shifter arm pivot and O-ring to transmission case and reverse shifter arm.

i. Secure reverse shifter arm pivot to case with the shifting arm pivot taper pin.

j. Tilt the transmission on its side and with the dummy shaft still in position, roll the countershaft gear assembly and thrust washers into position in the transmissions.

k. Slide the main drive gear assembly into the bore of the transmission. Install outer snap ring.

l. Tilt the mainshaft assembly into the transmission and insert the front of the mainshaft into the roller bearing section of the main drive gear.

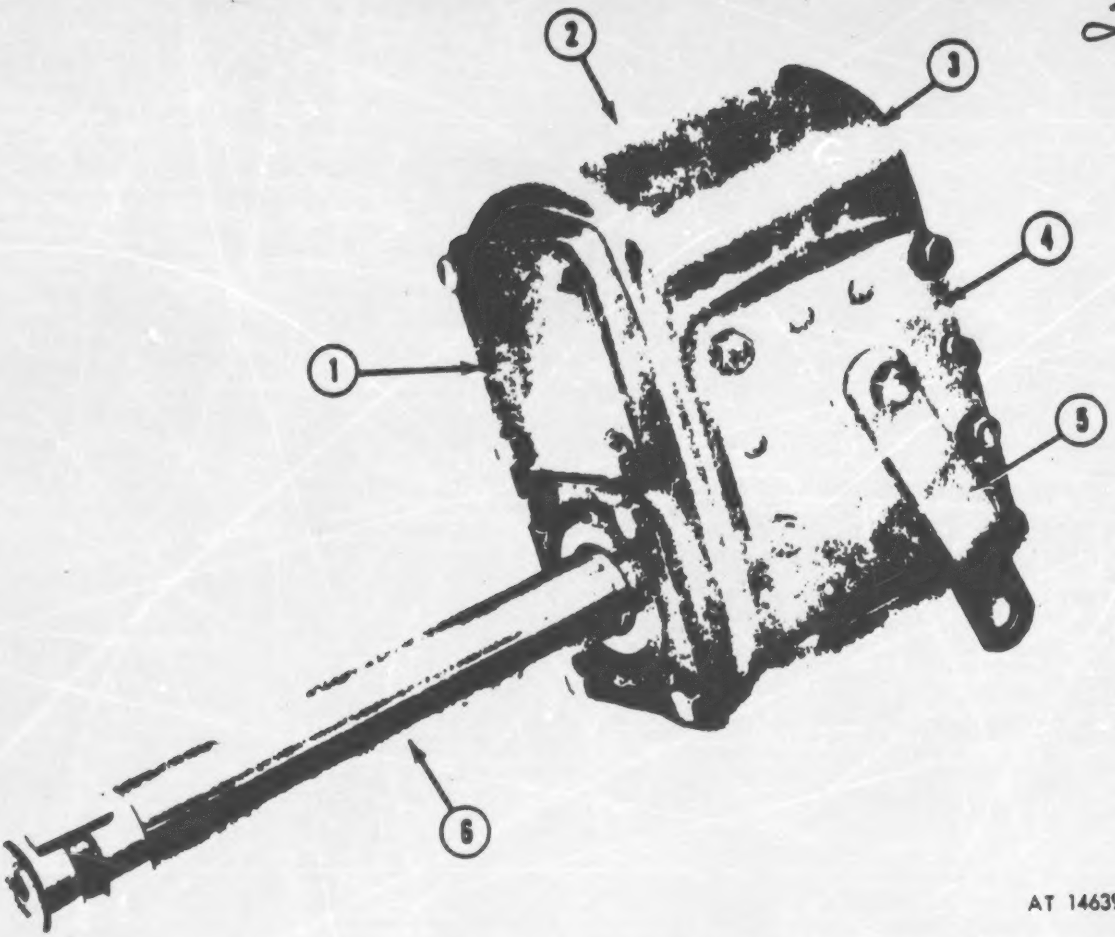
m. Install the rear mainshaft bearing and snap ring.

n. Align the lock plate slots in the reverse idler shaft and countershaft and install the lockplate. Secure the lockplate with the cap screw and lockwasher.

o. Align the countershaft gear assembly and thrust washers to the countershaft bores in the transmission and install the countershaft with the cockplate slot facing "out".

Note. Make sure the countershaft is kept in direct contact with the dummy shaft at all times to prevent dropping the bearing rollers or thrust washers.

p. Install the front bearing retainer gasket, bearing retainer and secure with the four cap screws and lockwashers.



AT 14639

1 Bearing end cap
2 Mounting flange
3 Housing
4 Shifter cover
5 Shifter lever
6 Drive shaft

Figure 07-5. Transmission power take-off.

q. Install the mainshaft spacer collar, rear bearing retainer gasket and rear bearing retainer assembly, and secure in place with the five retaining cap screws and lockwashers.

r. Install the rear bearing retainer oil seal.

Note: Install the oil seal with the lip of the seal facing forward.

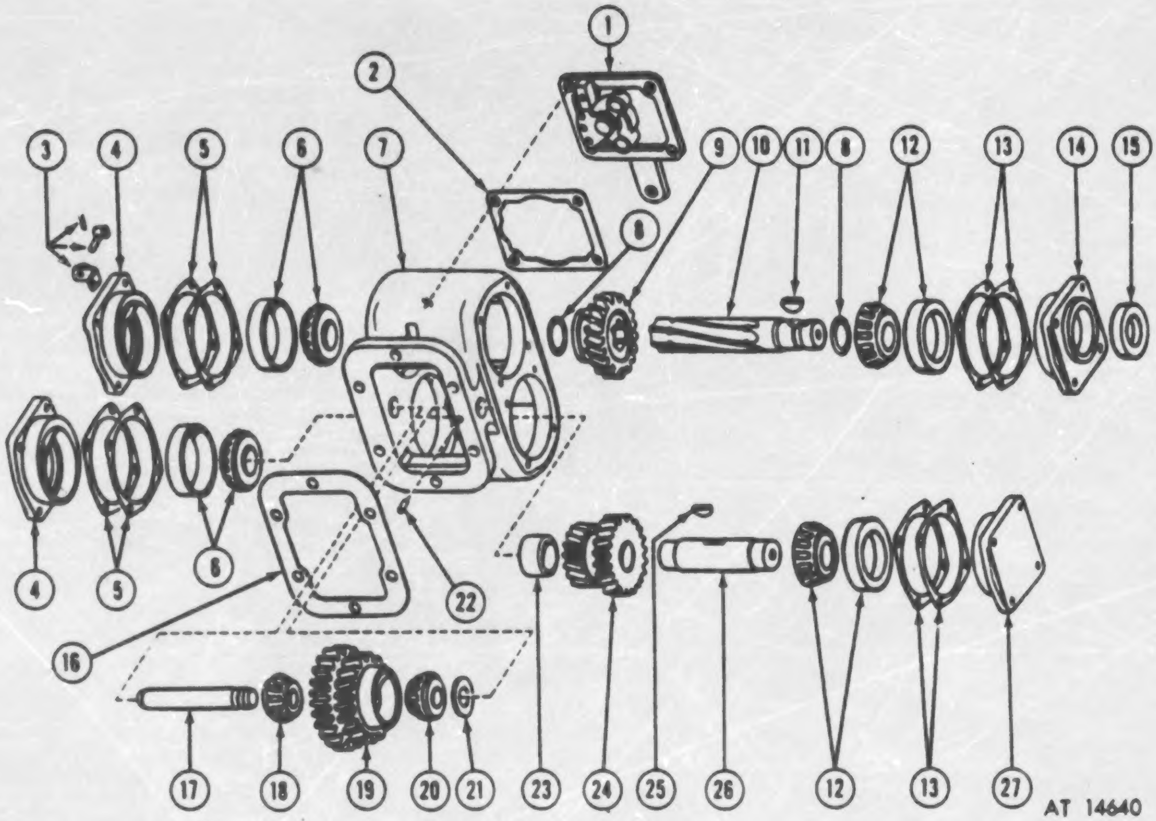
s. Install the propeller shaft flange, and nut. Torque tighten the propeller shaft flange nut to 125 lb-ft. and secure with a cotter pin.

t. Place the transmission gears in neutral and install the transmission control housing gasket and control housing. Secure with the six cap screws and lockwashers.

07–14. Transmission Installation

Install the transmission in reverse order of removal, refer to paragraph 07–2.

Note. When installing the transmission check the transmission-to-clutch housing adapter plate for looseness. If found loose, the plate must be checked for alignment with the crankshaft. Attach a special tool and dial indicator gauge over the inside circumference of the clutch pressure plate, and rotate the crankshaft slowly noting the dial gauge reading. The maximum allowable run out is 0.005". If the dial gauge reading exceeds the allowable run out, loosen the plate and reposition the adapter plate as necessary until the correct alignment is obtained.



1 Shifter cover and lever
2 Shifter cover gasket
3 Assembly, wire control bracket, swivel eye bolt and cotter pin
4 Bearing end cap
5 Bearing cap gasket
6 Tapered roller bearing
7 Housing
8 Lock ring
9 Sliding gear
10 Drive shaft
11 Woodruff key
12 Tapered roller bearing
13 Bearing cap gasket
14 Bearing end cap (open)
15 Oil seal
16 Mounting gasket
17 Idler gear shaft
18 Tapered roller bearing
19 Idler cluster gear
20 Tapered roller bearing
21 Idler gear spacer
22 Setscrew
23 Reverse idler gear spacer
24 Reverse idler gear cluster
25 Woodruff key
26 Reverse idler shaft
27 Bearing end cap (closed)

Figure 07–6. Transmission power take-off.

07–15. Power-Take-Off

The winch driver reversible power-take-off, figure 07–5, is mounted to left side of the transmission housing and is lubricated by the transmission lubricant oil. It is controlled by a three position shift lever located on the cab floor to the right of the driver's seat, adjustable rod connects the shift lever to the shift lever of the power-take-off. When installing the power-take-off a new gasket should always be used and mounting bolts should be torqued 18 to 30 lb-ft. Adjustment of the power-take-off may be made by loosening the jam nut and adjusting the shifter rod as necessary.

When reinstalling the power take off on the transmission, the backlash between the power take off pen, and the transmission gear should be approximately 006" to 012" If too few gaskets are used, the unit will whine. If too many gaskets are used, the unit will clatter. When in doubt about the proper backlash, it may be advisable to remove the shifter cover and check backlash thru the cover opening by rocking the idler cluster gear, figure 07-6.

07-16. Transmission Specifications

Make	Warner
Model	98AT
Speed Ratios:	
First	6.398:1
Second	3.092:1
Third	1.686:1
Fourth	1.000:1
Reverse	7.820:1

CLUTCH

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02-1. General

A heavy-duty single plate, dry disc type clutch is used on the M715 and M725. The clutch assembly consists of the clutch driven plate assembly, the clutch cover and pressure plate assembly, and the clutch release mechanism.

The pressure plate is 10½" diameter and utilizes nine springs to ensure maximum pressure and positive engagement. The driven plate incorporates a damper assembly in the hub to minimize transmission of torsional vibrations from engine to transmission, and cushion springs to provide smooth engagement of engine power.

02-2. Clutch Maintenance

To obtain normal life and satisfactory performance from any clutch it must be correctly operated and properly maintained. Two conditions which shorten clutch life are continuous operation of the clutch release bearing and clutch slippage. The clutch release bearing is designed for intermittent use. If run continuously the bearing lubricant will become exhausted causing the bearing to become dry, noisy, or seized resulting in clutch finger wear. The clutch must be properly adjusted so that the release bearing is free of the clutch fingers at all times, except when the clutch pedal is depressed.

Clutch slippage occurs when the vehicle is overloaded, the vehicle load is applied too quickly, or when the pressure of the clutch fingers is only partially applied to the clutch plate. Friction between the clutch facings, flywheel and pressure plate produces excessive heat causing burned, glazed and worn facings, resulting in shortened clutch life. Avoid clutch slippage under heavy loads by using lower gear or reducing the load.

02-3. Clutch Linkage

The clutch linkage is a mechanical type consisting of the clutch pedal, an adjustable rod that connects the pedal to the cross shaft, the cross shaft idler that transfers the movement of the clutch pedal to the required plane, and a link that connects the cross shaft to the throwout lever. Refer to figures 02-01 and 02-2. Pressing the clutch pedal moves the external end of the throwout lever toward the rear of the vehicle. The throwout lever pivots and slides the throwout bearing forward to disengage the clutch.

02-4. Clutch Linkage Adjustments

Refer to figures 02-01 and 02-2.

To adjust clutch linkage, the following adjustment sequence should be followed:

a. Disconnect the adjusting rod from the clutch pedal. Turn the adjusting nut in or out of the clutch bracket to position the clutch

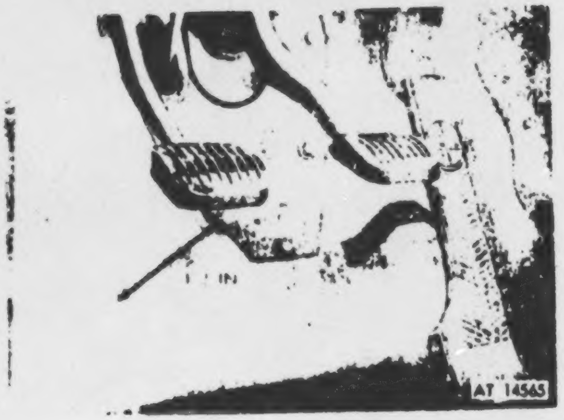


Figure 02-1. Clutch pedal-to-toe panel measurement.

pedal. Hold a ruler perpendicular to the toe-riser panel and adjust pedal stop until top of clutch pedal pad is 7½ in. minimum from toe riser panel to 1½" above the brake pedal, as shown in figure 02-1.

b. With the clutch pedal positioned up against the adjusting bolt, adjust the length of the rod so that it can be connected to the pedal with a 49° angle maintained between the frame and cross shaft at the point indicated in figure 02-2.

c. To adjust clutch free pedal, adjust the cross shaft-to-throwout lever link so that the clutch pedal can be pressed ¾" to 1" before clutch disengagement starts.

02-5. Clutch Pressure Plate and Disc

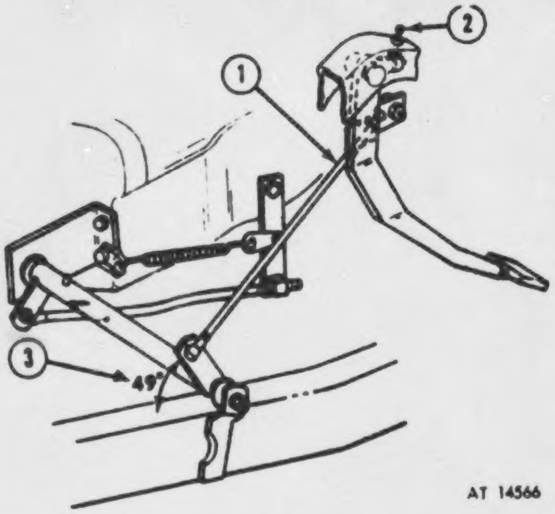
02-6. Clutch Pressure Plate and Disc Removal

The following procedure covers removal of the clutch disc and pressure plate. Refer to figure 01-13, section 01.

a. Refer to transmission section (07) for the removal of the transmission.

b. Remove the lower housing cover from the flywheel housing.

c. Mark the clutch cover, pressure plate and flywheel so that the original assembly positions can be restored during reassembly. Refer to figure 02-3.



1 Adjusting rod
2 Adjusting bolt
3 49° angle

Figure 02-2. Clutch linkage and clutch pedal adjustments.

d. When removing the clutch cover from the flywheel, loosen each cap screw a few turns at a time until the spring tension on the cover has been released. The clutch cover is a steel stamping which could be distorted by incorrect removal, resulting in clutch chatter or shifting difficulties when reinstalled.

02-7. Release Bearing Yoke and Shaft

Refer to figure 02-4.

If the release bearing yoke or shaft should be bent, cracked, or excessively worn it can be removed as follows:

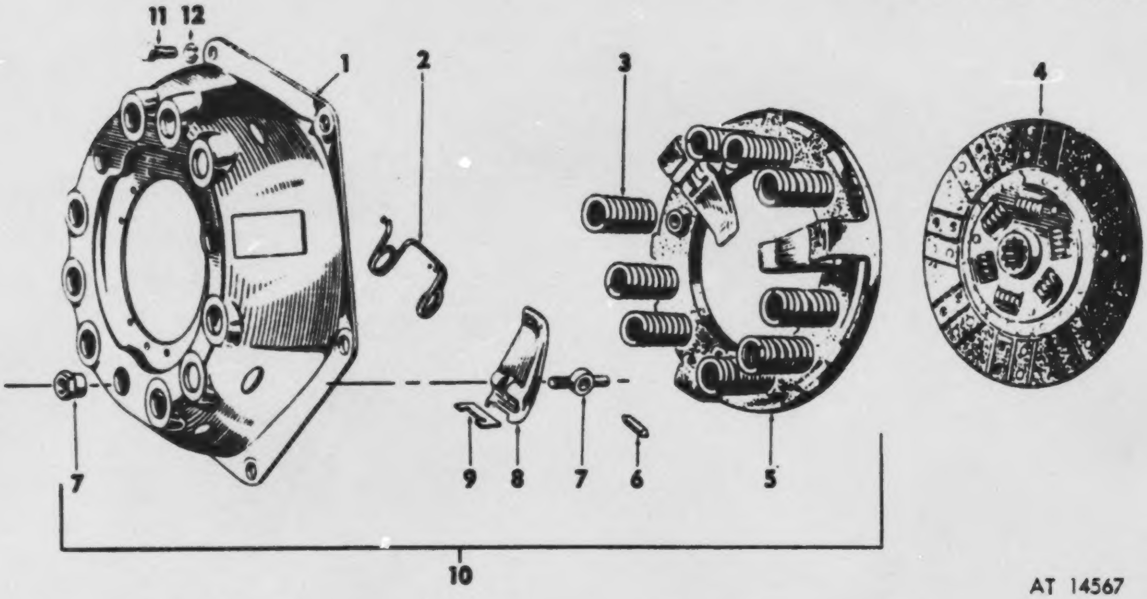
a. Cut the lockwire and remove the lock screw. Remove the yoke spring.

b. Pull the shaft from the clutch housing. Remove the yoke.

c. To install the release bearing yoke and shaft, reverse the removal procedure. Torque the lock screw 28 to 30 lb-ft.

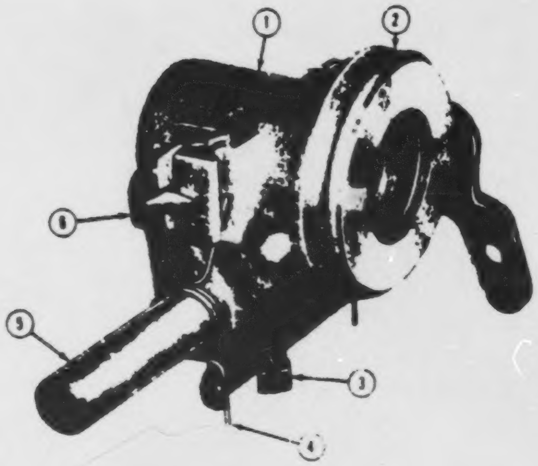
02-8. Pilot Bushing

Inspect the transmission main drive gear bushing located in the center of the crankshaft. If the bushing is excessively worn or damaged, replace it as follows:



1 Cover, pressure plate
2 Spring, anti-rattle
3 Spring, pressure
4 Plate and hub, driven
5 Plate, pressure
6 Pin, release lever
7 Bolt and nut
8 Lever, pressure plate
9 Strut, pressure plate
10 Clutch, assembly (less driven plate)
11 Bolt, hex hd., ⅜"-16 x ⅞"
12 Lock washer, ⅜"

Figure 02-3. Component parts of clutch.



1 Sleeve
2 Clutch release bearing
3 Lock screw
4 Yoke spring
5 Release bearing shaft
6 Release bearing yoke

Figure 02-4. Clutch release bearing.

a. Screw the tapered end of a pilot bushing removal tool into the pilot bushing.

b. Insert and rotate the puller until the pilot bushing is forced from the crankshaft.

c. To install a new bushing, slide the bushing into the end of a pilot bushing installing and burnishing tool and insert the bushing into the crankshaft. A soft hammer can be used against the tool to help drive the bushing in place.

d. Remove the installing and burnishing tool by tightening the cap and pressure nut. The bushing will be burnished to size as the tool to removed.

02-9. Clutch Lever Adjustment

Important: Always inspect release lever height adjustment when installing a new clutch drive plate.

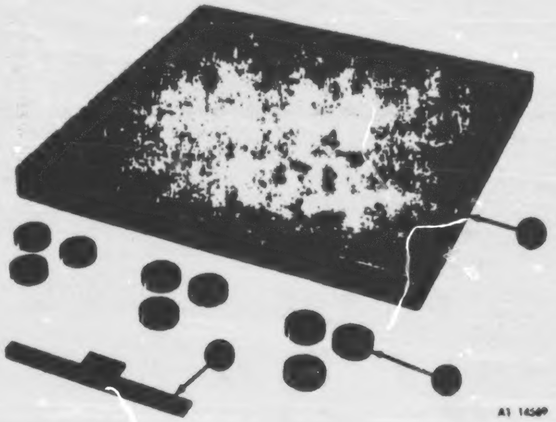
The clutch pressure plate adjustment must be checked before installing a new clutch. The proper spacer thickness and gauge length for the clutch is listed in paragraph 02–10. The gauge and spacers can be fabricated as described in paragraph 02–11. Proceed as follows:

a. Place the .305" spacers between the pressure plate face and the clutch adjusting fixture. Locate the spacers under the pressure plate fingers and at the center of the pressure plate face.

b. With the spacers properly installed, bolt the pressure plate to the adjusting fixture. Draw the bolts down evenly, a little at a time, until they are tight.

c. Using the $1\frac{15}{16}$ gage length, check the lever adjustment.

d. Turn the lever adjusting nut until the top of the fingers touch the $1\frac{15}{16}$" step on the fabricated gauge. Before staking the adjusting nuts to lock them in place, work the levers up and down and recheck the adjustment again. Stake the nut with a dull punch.



1 Mounting fixture   2 Spacers   3 Gauge

Figure 02–5. Clutch adjusting fixture.

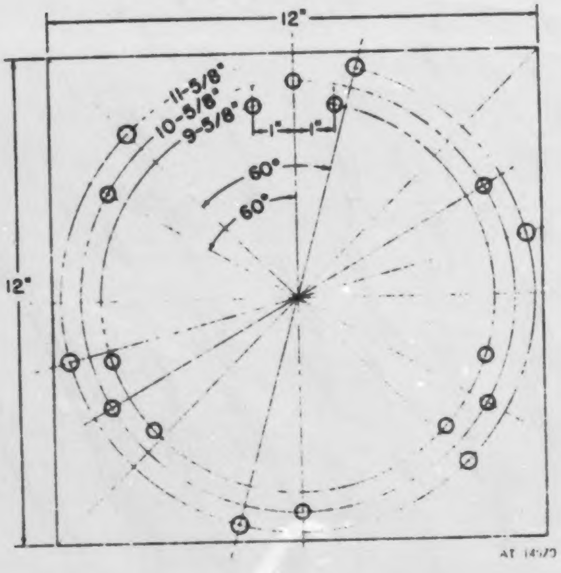


Figure 02–6. Mounting fixture hole dimensions.

02-10. Clutch Adjusting Fixture Data

Disc diameter	*Spacer thickness*	*Gauge length*
10⅛"	.305"	1 15/16"

02-11. Fabricating teh Clutch Fixture

a. For the mounting fixture, as shown in figures 02-5 and 02-6, select a flat steel plate 1" x 12" x 12".

Drill and tap six equally spaced holes ⅜" x 16 thread on a 15⅝" diameter bolt circle.

b. From steel bar stock any size from ½" to 1½", make three spacers .305 of an inch thick. Each spacer should be hardened and ground to size and the dimensional thickness stamped thereon.

c. From flat bar stock at least ⅛" thick make a gauge as shown in figure 02-7. Harden, grind to size, and stamp sizes on the gauge.

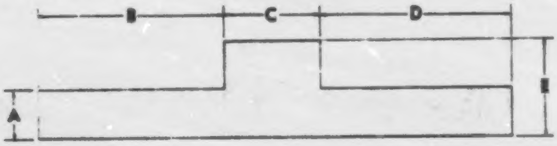


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Figure 02-7. Gauge fabricating dimensions.

A—½" B—1 15/16" C—1" D—2" E—1"

02-12. Clutch Lever Positions

When the clutch pedal is depressed, the release bearing is moved toward the flywheel and contacts the inner ends of the release levers. Each lever is pivoted on a floating pin which remains stationary in the lever and rolls across a short flat portion of the enlarged hole in the eyebolt. The outer ends of the eyebolts extend through holes in the stamped cover and are fitted with adjusting nuts to secure the levers in the correct position. The outer ends of the release levers engage the pressure plate lugs by means of fulcrums, which provide knife-edge contact between the outer ends of the levers and the lugs.

02-13. Clutch Installation

The procedure for the installation of the clutch is as follows:

a. Place a small amount of light cup grease in the pilot bushing.

b. Install the clutch disc with the short hub facing the flywheel.

c. Install the pressure plate, properly aligning the marks made on removal.

d. Use clutch disc aligning arbor W-327 or a spare transmission main drive gear to hold the clutch disc in place while installing the pressure plate-to-flywheel bolts.

e. Tighten the pressure plate-to-flywheel bolts evenly, a little at a time. Torque these bolts 25 to 35 lb-ft.

f. Replace the release bearing.

g. Refer to transmission section (07) for the installation of the transmission.

02-14. Clutch Throwout Release Bearing

The clutch throwout or release mechanism consists of a release bearing and sleeve assembly pivoted on a release bearing yoke mounted on a cross shaft which is mounted in bushings at both sides of the clutch bell housing.

Never wash the clutch release bearing in gasoline or any solvent that will dissolve the lubricant. It is neither necessary or possible to lubricate this bearing at any time. Connect linkage to the throwout release lever. Adjust free play as directed in paragraph 02-4.

02-15. Clutch Housing Alignment

Misaligned clutch housings can cause improper clutch release, driven plate failure, front transmission bearing failure, uneven wear in crankshaft pilot bushings, clutch "cackle" noise, vibration and, in extreme cases of misalignment, "jumping out of gear" on deceleration. Should any of these malfunctions occur, the rear face of the flywheel housing should be checked for alignment and concentricity of transmission pilot bore with center line of crankshaft, as follows:

a. Install a clutch shaft aligning tool in the crankshaft pilot bushing and mount dial indicator on the end of the tool. The clutch shaft aligning tools may be altered to insure a secure fit in the pilot bushing in the crankshaft. Saw

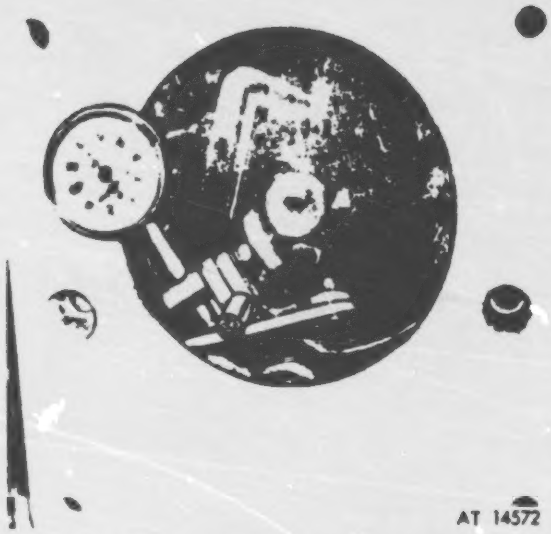


Figure 02–8. Dial indicator location.

a slot down approximately one inch in the end of the tool that enters the pilot bushing. Spread the end of the tool with a thin chisel so that the tool fits securely in the pilot bushing when tapped into place.

b. Install dial indicator on the tool and locate the indicator so that it contacts the rear face of clutch housing approximately 1/8" from the edge of the rear opening (figure 02–8).

Note. Dial indicator holding tool must be held firmly in crankshaft pilot bushing when taking either reading.

c. Check squareness of face of housing by turning the crankshaft. Total indicator reading should not exceed .005". Crankshaft end play must be held to zero when checking face alignment.

d. To correct indicated misalignment of the clutch housing, install shims between the clutch housing and the engine to clutch housing spacer to bring the indicator reading on the face of the housing within the specified limits. To install the shims, loosen the clutch housing assembly and locate shims where necessary by loosening the bolts and inserting the shims in place. Tighten the bolts and recheck the face alignment. Total indicator reading on the face of the flywheel housing should not exceed .005". Relocate shims if necessary to bring reading within limits.

e. To check bore alignment, locate the dial indicator on the inside diameter of the rear opening of the clutch housing. Rotate the engine and note the indicator reading at four equally spaced points. Total indicator reading must not exceed .005".

f. Any change in face alignment will change bore alignment. Therefore, it may be possible to correct bore alignment by changing the face alignment. Where it is impossible to correct the bore alignment to a maximum of .005" run-out with change of face alignment (not to exceed .005") replace the housing.

02–16. Service Diagnosis

Symptoms	*Probable remedy*
Clutch Chatter:	
Grease on the clutch driven plate facings	Install new driven plate
Binding of the clutch linkage	Free and adjust linkage
Loose or damaged clutch driven plate facings	Install new driven plate
Loose engine mountings	Tighten mounting screws
Incorrect adjustment of clutch pressure levers	Adjust levers
Misalignment of clutch housing	Align clutch housing
Loose driven plate hub	Install new driven plate
Clutch Grabbing:	
Oil or grease on clutch driven plate facings	Install new driven plate
Broken pressure plate	Replace presure plate
Clutch driven plate binding on transmission clutch shaft	Correct binding. Replace parts if damaged
Clutch Slipping:	
Incorrect adjustment of clutch pedal	Adjust pedal
Lack of lubrication in clutch linkage	Lubricate
Broken clutch pressure springs	Replace springs
Weak pressure springs	Replace springs

Symptoms	Probable remedy
Clutch Dragging:	
Incorrect adjustment of clutch pedal	Adjust clutch linkage
Incorrect pressure lever adjustment	Adjust pressure
Loose or broken facings	Install new driven plate
Bent or dished clutch driven plate due to overheating	Install new driven plate

02-17. Clutch Specifications

Clutch size and type	10.50" Dry Plate	Area (Sq. In.)	106.75"
		Facing Thickness	0.125"
Rated Torque Capacity	290 lb-ft.	Pressure Plate	10.50"
Disc:		Springs:	
Outside Diameter	10.5"	Total Pressure	1640 lb.
Inside Diameter	6.5"	No. of Springs	9

REAR AXLE

Paragraph
General ---------------------------------------11-1
Rear axle shaft removal and installation --------11-2

Rear axle assembly

Differential bearing preload and ring gear backlash adjustment -----------------11-11
Differential side gear adjustment -----------------11-9
Axle assembly -----------------------------------11-10
Axle disassembly ---------------------------------11-5
Inspection and servicing -------------------------11-3
Pinion and differential cone and roller removal ----------------------------------11-6
Pinion bearing cup removal ----------------------11-7
Rear axle assembly removal ----------------------11-4
Rear axle assembly installation ------------------11-12
Trouble shooting differential ---------------------11-13
Service diagnosis ---------------------------------11-14
Rear axle specifications ---------------------------11-15

11-1. General

Full-floating front and rear axles are standard on the vehicles.

The axle model number is cast into the housing as illustrated in figure 11-1.

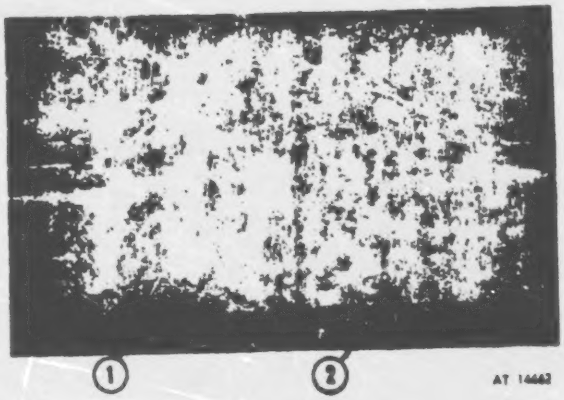
A metal tag under two of the differential housing cover screws is stamped to identify the number of teeth in the drive gear and pinion, figure 11-1. To determine the axle ratio, divide the larger number (ring gear teeth) by the smaller number (pinion teeth). This section contains information for servicing the rear axles. Information for wheel bearing adjustment is given in section 13.

11-2. Rear Axle Shaft Removal and Installation

Refer to figure 11-2.

To remove the full-floating axle shaft, it is not necessary to jack up the rear wheels. Procedure is as follows:

a. Remove the axle flange nuts, lockwashers, lift hook bracket, and split washers holding the axle shaft flange.



1 Ratio 2 Axle model

Figure 11-1. Axle model and ratio identification.

b. Pull the axle shaft free from the housing.

c. A broken axle shaft can be removed from a full-floating axle by removing the opposite axle shaft and inserting a pipe which will drive the broken axle shaft out.

The installation of the rear axle shaft is the reverse of the removal.

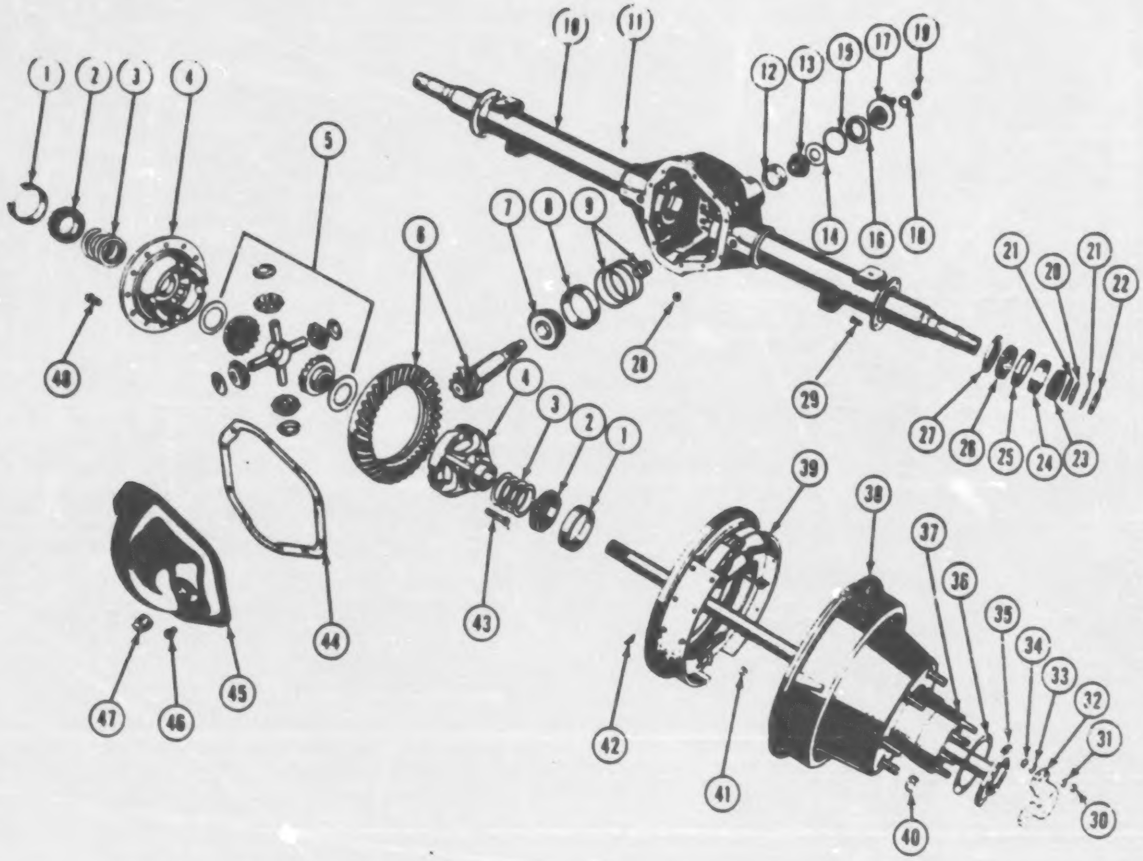
11-3. Inspection and Servicing

Refer to figure 11-2.

Servicing of the differentials of both front and rear axles is covered in paragraph 11-5 through 11-11. Before disassembling the differential, it is advisable to determine through inspection the cause of the failure. Inspection procedure is as follows:

a. Drain lubricant and remove housing cover and gasket.

b. Clean the differential parts thoroughly with solvent.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1	Differential bearing cup
2	Differential bearing cone and rollers
3	Shims
4	Differential case
5	Differential gear set
6	Ring gear and pinion
7	Pinion inner bearing cone and rollers
8	Pinion inner bearing cup
9	Pinion shims
10	Axle housing
11	Vent plug
12	Pinion outer bearing cup
13	Pinion outer bearing cone and rollers
14	Oil slinger
15	Yoke gasket
16	Pinion oil seal
17	Yoke
18	Washer
19	Nut
20	Nut
21	Lock washer
22	Nut
23	Outer bearing cone and rollers
24	Outer bearing cup
25	Inner bearing cup
26	Inner bearing cone and rollers
27	Seal
28	Drain plug
29	Bolt
30	Nut
31	Lock washer
32	Lifting bracket
33	Spacer
34	Split lockwasher
35	Axle shaft
36	Gasket
37	Hub
38	Brake drum
39	Brake assembly
40	Wheel lug nut
41	Nut
42	Dust plug
43	Cap screw
44	Cover gasket
45	Housing cover
46	Screw and locker washer
47	Filler plug
48	Cap screw

Figure 11-2. Fullfloating rear axle.

c. Carefully inspect all parts.

Should it be determined by inspection that the differential requires overhauling, the axle must first be removed from the vehicle.

Note. All service replacement axle assemblies are shipped from the factory without lubricant in the differential. Lubricant must be added to the differential before the axles are installed in vehicles. Use the grade and quantity of lubricant specified in the appropriate service manual. After the axle has been installed in the vehicle, check to be sure the lubricant level in the differential is up to the filler plug opening.

11–4. Rear Axle Removal

To remove the rear axle, proceed as follows:

a. Raise the rear of the vehicle with a hoist. Safely support the frame ahead of the rear springs.

b. Remove the wheels.

c. Disconnect the propeller shaft at the rear yoke.

d. Disconnect the shock absorbers at the axle mounting.

e. Disconnect the brake hydraulic hose at the bracket on the tubular cross member near the right frame side rail. Tape end of hose to keep out dirt. Disconnect breather hose.

f. Support the axle on a jack.

g. Remove the axle U-bolts.

h. Slide the axle from under the vehicle.

11–5. Axle Disassembly

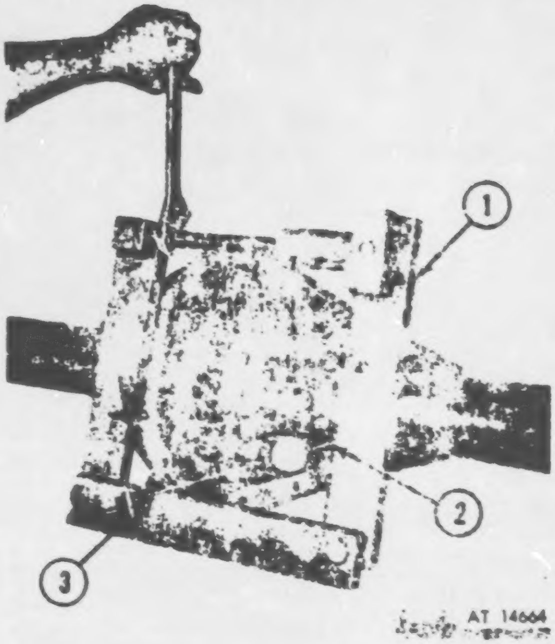
Refer to figure 11–2.

Procedure for disassembling the differential on full-floating axle is as follows:

a. Remove the axle shafts. Refer to paragraph 11–2 for rear axle removal.

b. Remove the housing cover and four cap screws holding the two differential side bearing caps in position. Make sure there are matching letters or some type of identification marks on the caps and housing so that each cap can be reinstalled in the same position and location from which it is removed.

c. Use Spreader W–129 as shown in figure 11–3 to spread the housing. Install hold-down clamps, to keep the spreader in position. Clamp on a dial indicator. From the side, measure the carrier spread. Do not spread the carrier more than .020".



1 Spreader W–129
2 Dial indicator and pointer
3 Dial indicator clamp

Figure 11–3. Differential carrier spreader.

d. Remove the dial indicator.

e. Carefully pry the differential case loose, using pry bars at the heads of the ring gear bolts and carrier casting.

f. Remove spreader immediately to prevent the possibility of the carrier taking a set.

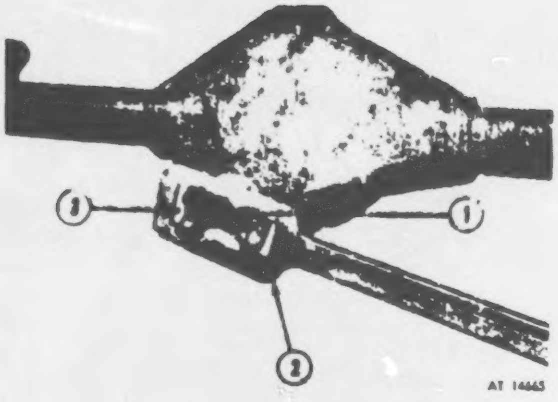
g. Remove the screws holding the ring gear to the differential case.

h. Mark the case halves for reassembly in their same relationship.

i. Separate differential case halves by removing attaching cap screws.

j. Carefully so as not to lose the thrust washers, remove the differential gear set.

k. With Tool C–3281 to hold the shaft as shown in figure 11–4, remove the nut. With Puller W–172 remove the yoke as shown in figure 11–5.



1 Nut 2 Wrench C-3281 3 Yoke

Figure 11-4. End yoke holding wrench.

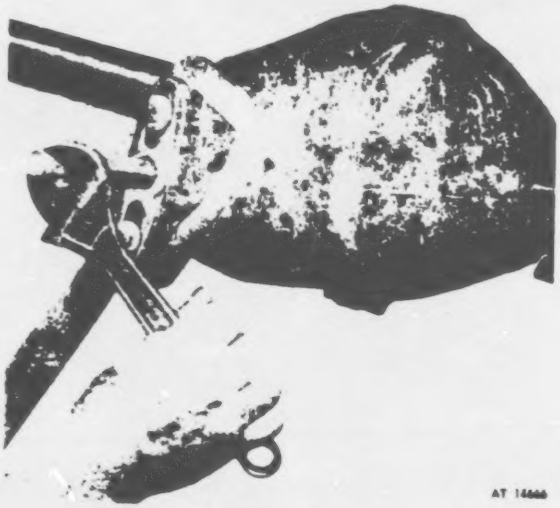


Figure 11-5. End yoke puller.

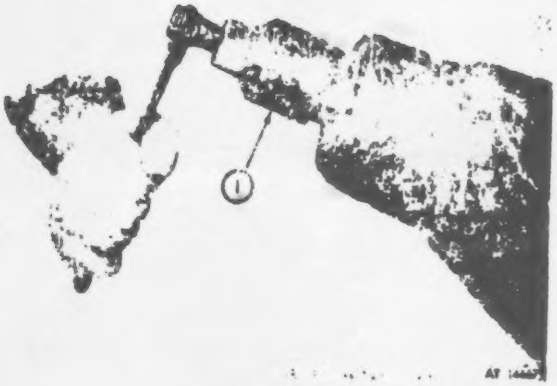
l. Remove pinion oil seal using Pinion Oil Seal Puller W-286, as shown in figure 11-6.

m. With a hammer and brass drift, drive on the end of the pinion shaft to force the pinion into the differential housing so that it may be removed.

11-6. Pinion and Case Bearings

Refer to figure 11-2.

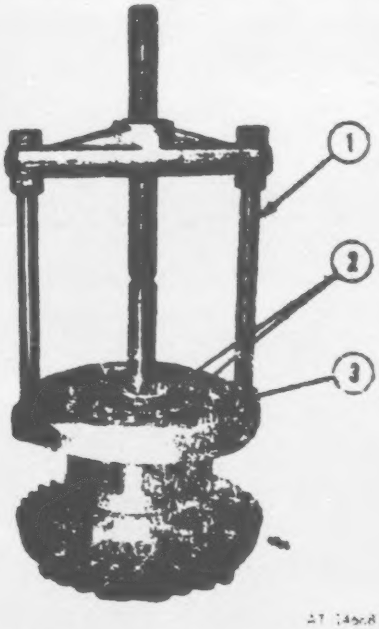
a. To remove differential bearing cones and rollers on model 70 rear axle and model 60 front axle, use Tool DD-914P with Holding Ring DD-914-8 and Adapter DD-914-62, as shown in figure 11-7.



1 Tool W-286

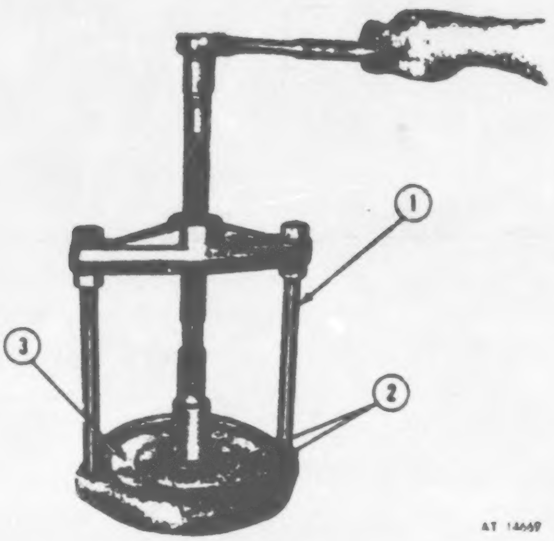
Figure 11-6. Pinion oil seal puller.

b. To remove the Model 70 rear axle pinion inner bearing cone and rollers, use Tool DD-914P with Holding Ring DD-914-8 and Adapter DD-914-95, as shown in figure 11-8. To remove the Model 60 front axle pinion bearing



1 Press DD-914-P
2 Adapter DD-914-62
3 Holding ring DD-914-8

Figure 11-7. Differential bearing cone and roller removal.



1 Press DD-914-P
2 Adapter DD-914-95
3 Holding ring DD-914-8

Figure 11-8. Pulling inner pinion bearing.

cone and rollers, use Tool DD-914P with Holding Ring DD-914-9 and Adapter C-293-37. When using an Arbor Press, DD-914-7 Extension and DD-914-42 Button are used.

11-7. Pinion Bearing Cup Removal

Refer to figures 11-9 and 11-10.

To remove the pinion inner and outer bearing cups, use Tool W-100-60-70, with its adapter plates. Remove the inner bearing cup first. Procedure for removal is as follows:

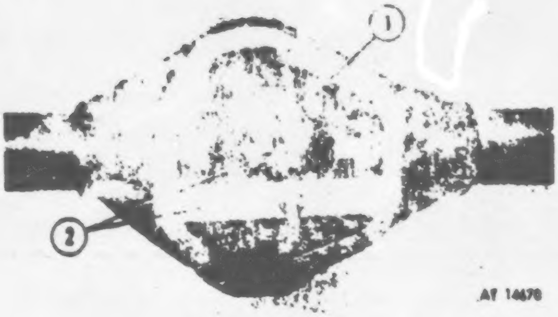
a. Remove the hex nuts from each end of Tool W-100-60-70.

b. From the housing cover end, carefully insert the round adapter with two flat sides through the inner bearing cup and position it behind the bearing cup shoulder.

c. Insert the short-threaded end of the main puller screw through the hole in this adapter and secure the adapter with a hex nut.

d. Position the plate across the open face of the differential housing and secure with a hex nut.

e. Make sure the adapter plate sets flat against the pinion rear bearing adjusting shims. Turn down the nut to remove the bearing cup.



1 Bearing cup
2 Tool W-100-60-70

Figure 11-9. Pinion inner bearing cup removal.

f. Remove Tool W-100-60-70 from housing cover end.

g. Attach Tool W-100-60-70 at yoke end of housing.

h. Insert adapter behind shoulder of outer bearing cup.

i. Make sure the adapter plate sets flat against the pinion outer bearing adjusting shims. Turn down the nut to remove the bearing cup.

11-8. Pinion Installation and Adjustment

Adjustment of the pinion is accomplished by the use of shims placed between the inner bearing and the axle housing and between the pinion shoulder and the outer bearing. The shims behind the inner bearing adjust the position of

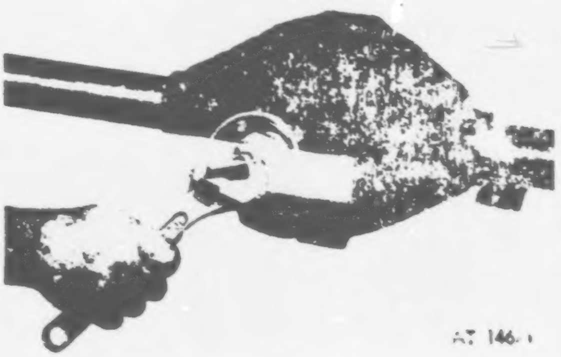
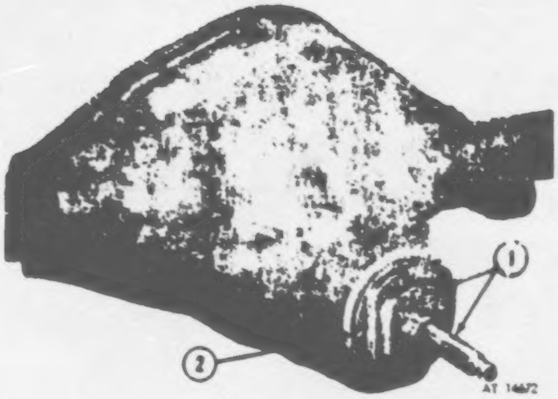


Figure 11-10. Pinion outer bearing cup removal.



1 Tool W-100-60-70 2 Outer bearing cup

Figure 11-11. Installing outer bearing cup.

pinion in relation to the ring gear. The shims behind the outer bearing adjust the pinion inner and the outer bearing preload. Install the pinion as follows:

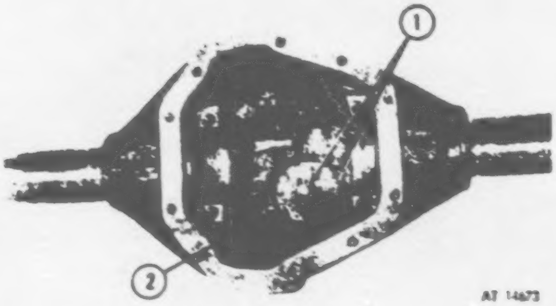
a. Install outer bearing cup using Tool W-100-60-70, as shown in figure 11-11.

b. Install the inner bearing cup using Tool 100-60-70, to pull the cup into the housing. See figure 11-12.

c. Use Tool C-3095 to press the inner bearing cone and roller onto the pinion shaft, as shown in figure 11-13.

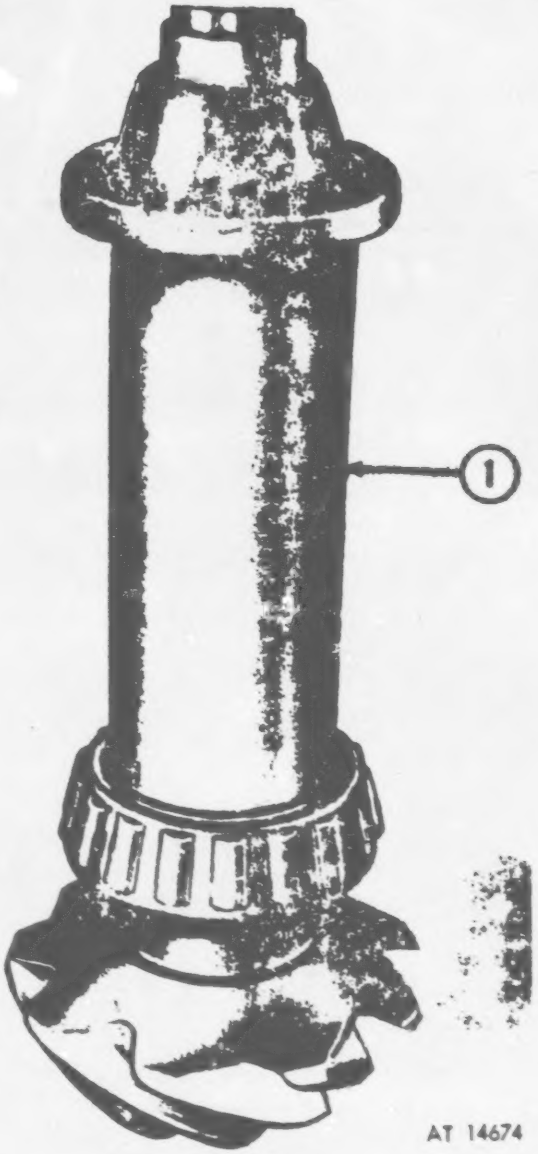
Note. On the model 60 front axle, install inner pinion oil slinger onto the pinion shaft before pressing inner bearing onto the opinion shaft.

d. Place the pinion in the housing and install a .065" shim, the inner cone and roller, and the pinion nut.



1 Tool W-100-70 2 Inner bearing cup

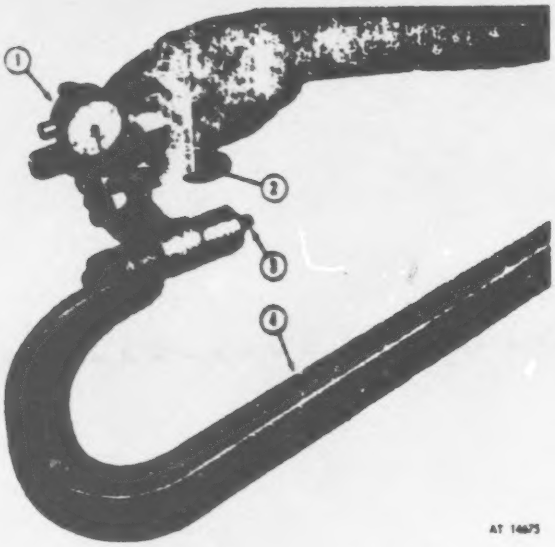
Figure 11-12. Installing inner bearing cup.



1 Sleeve C-3095

Figure 11-13. Pinion bearing installing sleeve.

e. Select the proper pinion adjusting gauge to obtain the correct reading. The pinion adjusting fixture must first be set by the use of a master gauge which is included in the W-99-B-60-70 kit. The gauge block supplied with the W-99-B-60-70 Master Gauge Set is stamped with the letter J. Use the J step for



1	Dial indicator	3	Stationary pin
2	Gauge block	4	C-clamp

Figure 11-14. Setting pinion gear.

setting the Model 60 axle pinion and the opposite side when setting the Model 70 axle pinion. See figure 11-14.

Note. When setting Model 70 axle differentials, Spacer W-99-19 must be inserted on the stationary pin between the housing (No. 10, fig. 11-15) and the pinion head.

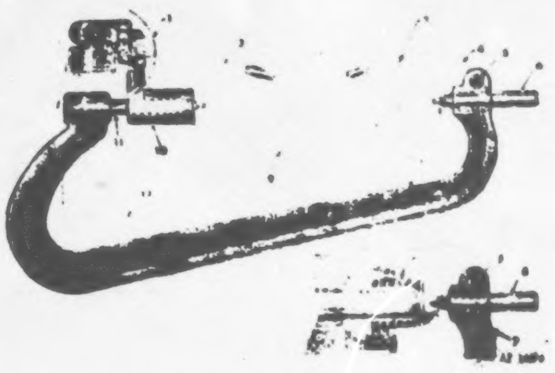
After selecting the proper gauge, the adjusting fixture can be set as follows:

f. Place the gauge block against the machined surface of the dial indicator mount. See figure 11-14.

g. Set the dial indicator on zero by rotating the face.

h. Install the pinion adjusting fixture on the pinion with the stationary guide pin and the adjustable guide pin seated in the pinion shaft lathe centers, as shown in figure 11-15.

i. Seat the gauge mount firmly on the pinion head and swing the dial indicator through the differential bearing bore as shown in figure 11-16. The lowest reading indicates the center of the differential bearing bore. At this point the dial indicator should read the same as mark etched on the pinion head. If the reading does not agree, add or remove shims behind the bearing cup until the readings agree.



1	Dial gauge swing arc	7	C-clamp
2	Pinion	8	Sleeve
3	Flange	9	Inner bearing
4	Yoke	10	Housing
5	Thumb screw	11	Stationary guide pin
6	Guide pin	12	Pinion housing

Figure 11-15. Pinion adjusting fixture.

j. When the correct adjustment is reached, remove the pinion adjusting fixture and sleeve. Install outer bearing.

k. Install only the oil slinger, the yoke, the flat washer, and the pinion nut. Holding the yoke with Flange Holder C-3281, torque the nut 225 to 275 lb-ft. for full-floating rear axle.

l. Using Inch-Pound Torque Wrench on the nut, check the rotating torque. The rotating torque should be 10 to 25 lb. inches.

Note. Disregard starting torque.

m. Add or remove shims between the pinion outer bearing and the pinion shaft to obtain correct torque reading.

11-9. Adjustment of Differential Side Gear

Clearance between the differential side gears and differential case should be .000" to .006". Procedure for checking clearance is as follows:

a. With the differential positioned as shown in figure 11-16, tap the differential lightly on a flat surface so the differential gears settle into proper position.

b. Measure the clearance between side gears and the case with leaf feeler gauge as illustrated.

c. If the clearance exceeds .006", add shims between the side gears and the case. To bring the clearance within specified tolerance, shims

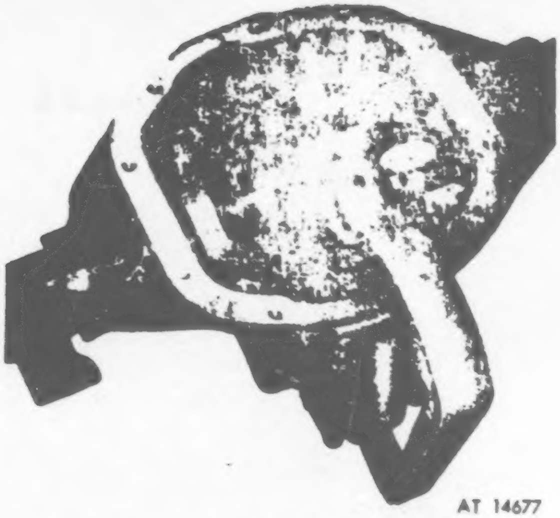


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Figure 11-16. Checking pinion adjustment.

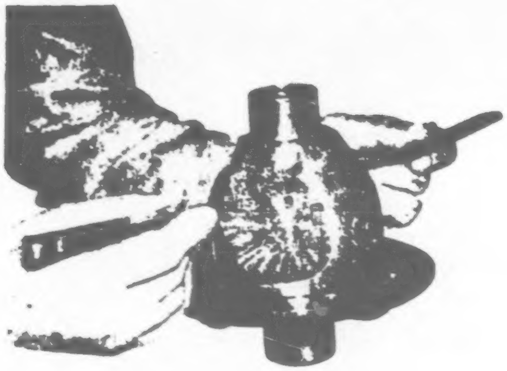

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Figure 11-17. Checking side gear clearance.

in these thicknesses are available .004", .006", .008". If shims are required, at least one shim should be placed on each side and the shim packs kept as even as possible. After adding shims, repeat the clearance check.

11-10. Axle Assembly

Refer to figure 11-2.

a. Assemble the differential gear set.

b. Install the differential gear set in the differential case. Align the marks made on disassembly and fasten the case together with cap screws. Torque screws 35 to 55 lb-ft.

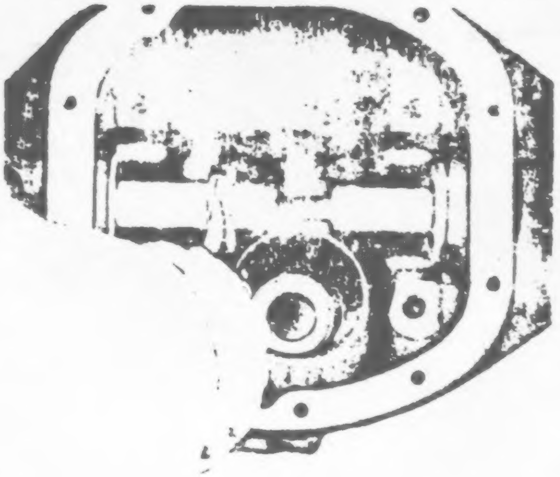

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Figure 11-18. Installing inner oil seals. (model 60 front axle)

c. Check side gear clearance as described in paragraph 11-9.

d. Align the marks made on disassembly. Install the ring gear on the differential case.

e. Install cap screws. Torque screws 100-120 lb-ft.

11-11. Adjustment of Differential Bearing Preload and Ring Gear Backlash

Refer to figure 11-2.

The adjustment of the differential bearings is maintained by the use of shims placed between the differential case and the differential bearings. Procedure for adjusting bearing preload is as follows:

a. Install the differential case and bearings in the axle housing without shims and with the bearing cups snug.

b. Holding the ring gear in contact with the pinion and using a screwdriver blade to move the differential bearing cups toward the center, insert feeler gauge on each side between differential bearing cup and the axle housing.

c. After the shim pack requirement for each bearing has been established, remove the differential assembly. Make up shim packs and keep them separated.

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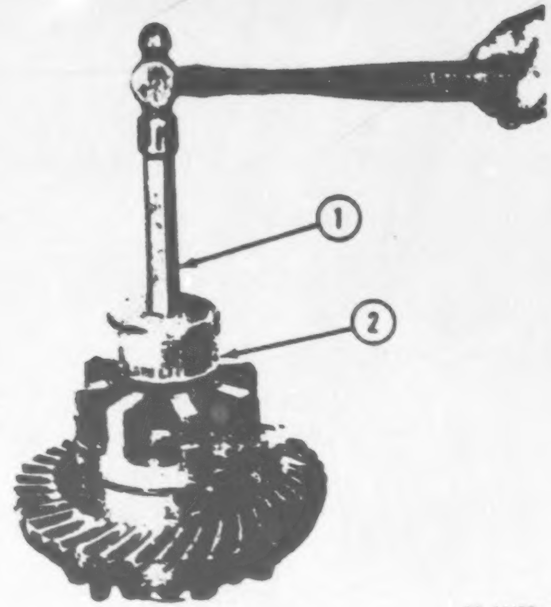


1 Driver C-4025 2 Bearing

Figure 11-19. Differential bearing driver.

d. Add an additional .015" thickness of shims to the pack on the tooth side of the ring gear.

e. Place the differential bearing shim packs on the differential case under each bearing. Install bearings with Driver C-4025. See figure 11-19.

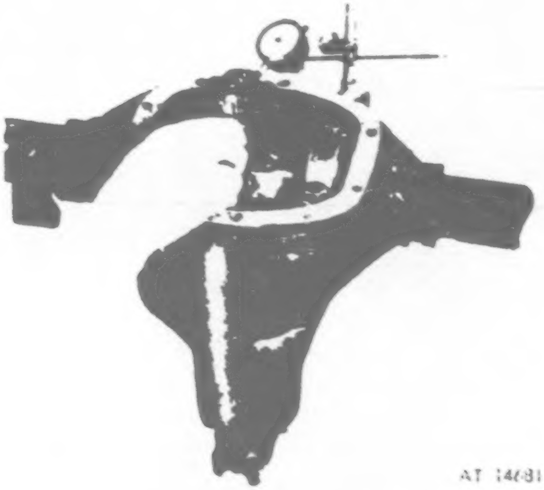
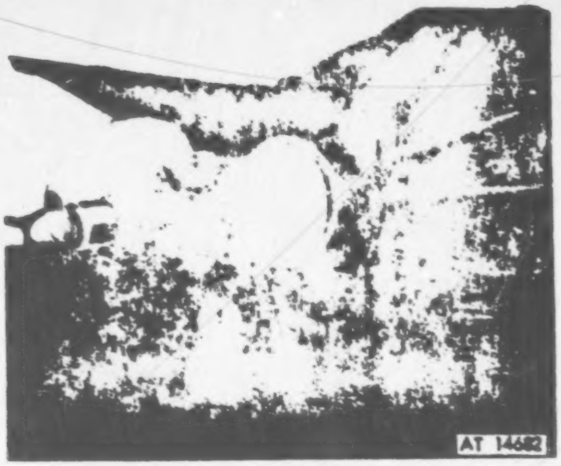


Figure 11-20. Checking ring gear backlash.



1 Tool C-359

Figure 11-21. Pinion shaft oil seal installer.

Note. When overhauling the Model 60 front full-floating axle differential, check the axle inner oil seals. Should new seals be required, install them, using DD-1243 Installer (fig. 11-18).

f. Attach the Carrier Spreader W-129, install a dial indicator, (figure 11-8) and spread the carrier a maximum of .020".

g. Remove the indicator.

h. Lubricate bearings and place the differential in the carrier.

i. Tap the unit carefully into place with soft mallet, making sure the ring gear teeth mesh with the pinion teeth.

j. Install bearing caps, matching their markings with those on the carrier.

k. Apply sealing compound to the screw threads. Torque the screws 70 to 90 lb-ft.

l. Install dial indicator to check ring gear backlash (figure 11-20). Check backlash at two points. If backlash does not fall within specifications, shims should be interchanged between the two differential bearing shim packs until correct backlash is obtained.

Note. Changing the position of a .005" shim from one side to the other will change the amount of backlash approximately .003".

m. Check ring gear for runout. A reading in excess of .006" indicates a sprung differential case, dirt between the case and the gear, or loose ring gear screws.

n. After the differential has been assembled and adjusted, the pinion shaft oil seal should be installed.

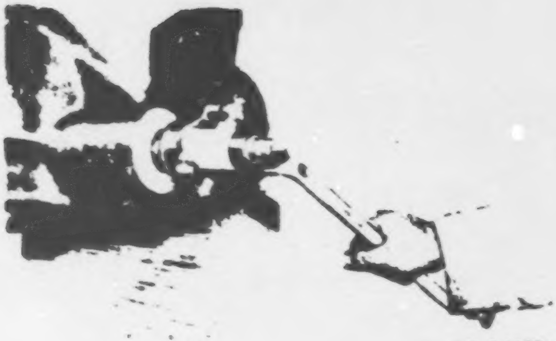


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Figure 11-22. Yoke installing tool.

o. Remove the sleeve previously installed in place of the yoke. Install the oil seal with Tool C-359 shown in figure 11-21.

p. Install the yoke with yoke installer, as shown in figure 11-22.

q. Install pinion nut and cotter pin.

r. Install axle shafts and housing cover.

11-12. Installing Rear Axle

Note. All service replacement axle assemblies are shipped from the factory without lubricant in the differential. Lubricant must be added to the differential before the axles are installed in vehicles. Use the grade and quantity of lubricant specified in section B.

After adding differential lubricant, suspend the axle with the axle shafts horizontal and the yoke end of the pinion housing hanging down, then twirl the pinion shaft several times to assure that the lubricant gets into the pinion shaft bearings.

Procedures for installing the rear axle is as follows:

a. Position the axle assembly under the vehicle.

b. Install spring to axle pad, U-bolts, nuts, and properly torque.

c. Connect the shock absorbers at the axle mounting pads.

d. Connect the propeller shaft at the rear universal joint.

e. Connect rear brake hose and bleed brakes.

f. Install wheels and lower vehicle to floor.

g. Fill the axle housing with the proper lubricant. For correct lubricant refer to section B.

11-13. Trouble Shooting Differential

Refer to paragraph 11-14.

11-14. Service Diagnosis

Symptoms	*Possible remedy*
Axle noisy on pull and coast:	
Excessive back lash bevel gear and pinion	Adjust
End play pinion shaft	Adjust
Worn pinion shaft bearing	Replace
Pinion set too deep in bevel gear (too tight)	Adjust
Axle noisy on pull:	
Pinion and bevel gear improperly adjusted	Adjust
Pinion bearings rough	Replace
Pinion bearing loose	Adjust
Axle noisy on coast:	
Excessive back lash in bevel gear and pinion	Adjust
End play in pinion shaft	Adjust
Improper tooth contact	Adjust
Rough bearings	Replace
Back lash:	
Worn differential pinion gear thrust washers	Adjust
Excessive back lash in bevel gear and pinion	Adjust
Worn universal joints	Replace

11-15. Rear Axle Specifications

Make	Dana
Model	70
Description	Full-floating hypoid gears
Drive pinion offset	1.12"
Number of differential pinions	4
Gear ratio	5.87:1
Ring gear outside diameter	10.5
Pinion adjustment	Shim
Pinion bearing adjustment	Shim

STEERING SYSTEM

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14–1. General

The steering system consists of the steering gear, steering wheel, steering column, flexible coupling, and steering linkage. See figure 14–1. This section covers wheel alignment, steering linkage, steering gear, steering column, and steering wheel.

14–2. Steering Gear Assembly

The steering gear is a reducing gear. It exchanges a relatively large amount of movement with a small force (applied by the driver at the steering wheel), for a much smaller amount of movement with a greatly increased force (through a cam and lever action). The steering gear ratio is 24 to 1.

14–3. Steering Linkage

Refer to figure 14–1.

The steering linkage consists of a steering arm attached to the steering gear, a connecting rod, tie rod, and steering knuckles integral with the tie rod. Ball joints are used on the tie rod and steering connecting rod to maintain constant toe-in and good steering control under all driving conditions. Should the ball joints be worn enough to allow excessive free motion in the linkage, they should be replaced. Ball joint replacement requires resetting the toe-in adjustment.

14–4. Front Wheel Turning Angle

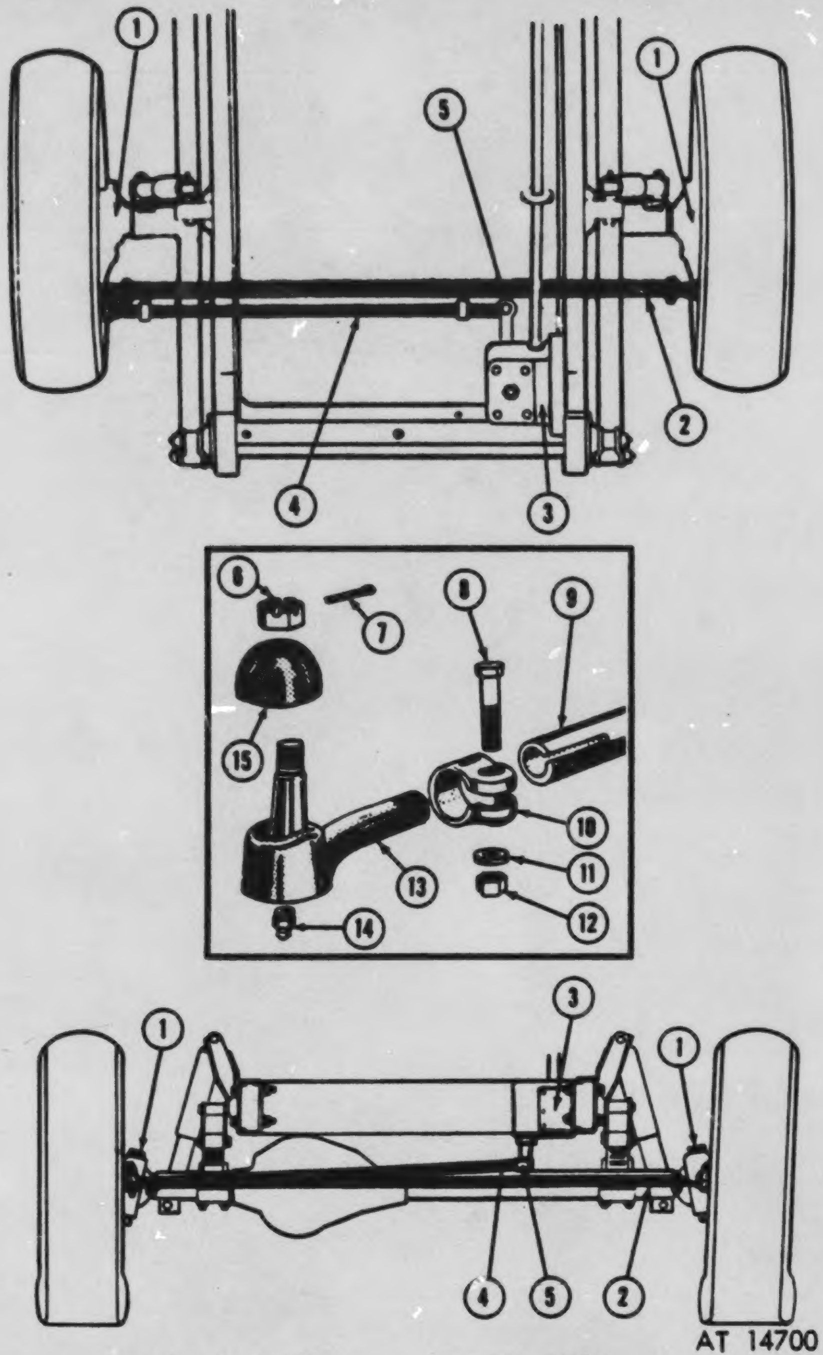
When the front wheels are turned, the inside wheel on the turn travels in a smaller circle than the outside wheel, therefore, it is necessary for the wheels to toe-out to prevent the tire on the inside wheel from being scuffed sideways. The angle for toe-out on turns is designed to permit both front wheels to turn on a common center.

14–5. Steering Arm

Should a steering arm become bent, the arm must be replaced, and the knuckle inspected for damage.

14–6. Front Wheel Alignment Adjustme

To insure correct alignment, a definite procedure for inspection of the steering system is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1	Steering knuckle
2	Tie rod
3	Steering gear
4	Connecting steering rod
5	Pitman arm
6	Castle nut
7	Cotter pin
8	Nut
9	Tie rod tube
10	Clamp
11	Lock washer
12	Nut
13	Ball joint
14	Lubrication fitting
15	Rubber seal

Figure 14–1. Steering linkage solid front axle.

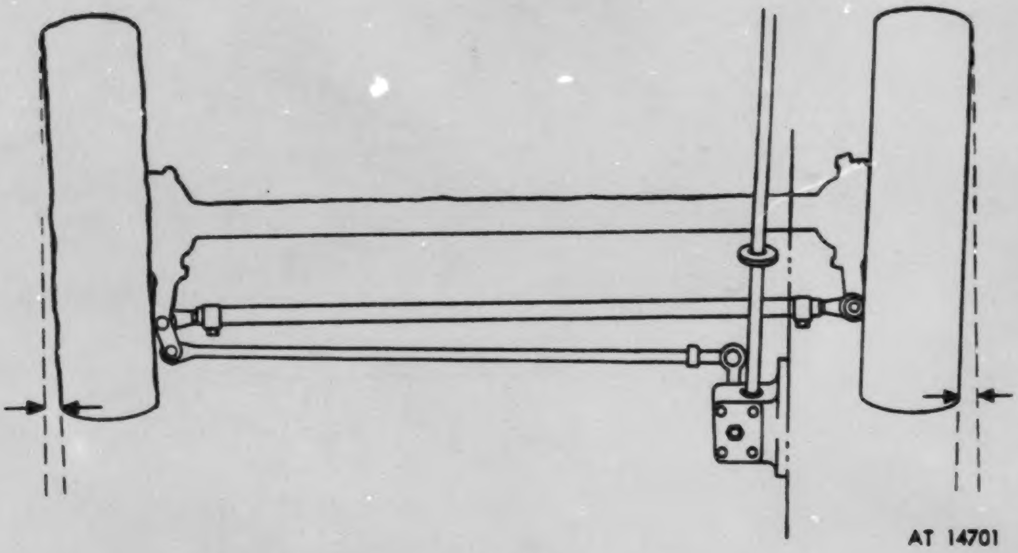
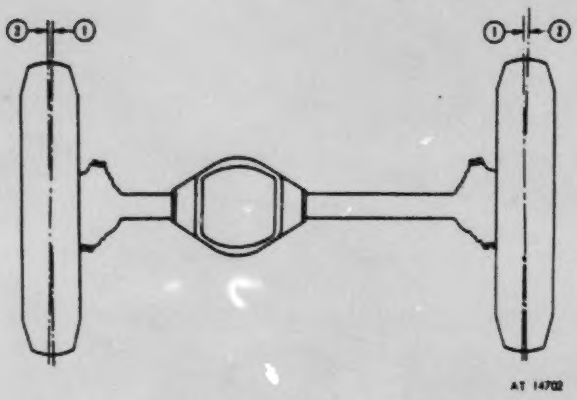


Figure 14-2. Front wheel toe-in (top view).



1 Vertical line 2 Camber

Figure 14-3. Front wheel camber.

recommended. It is suggested that the following sequence be used:

a. Equalize tire pressures and level vehicle.

b. Check steering gear to steering column alignment.

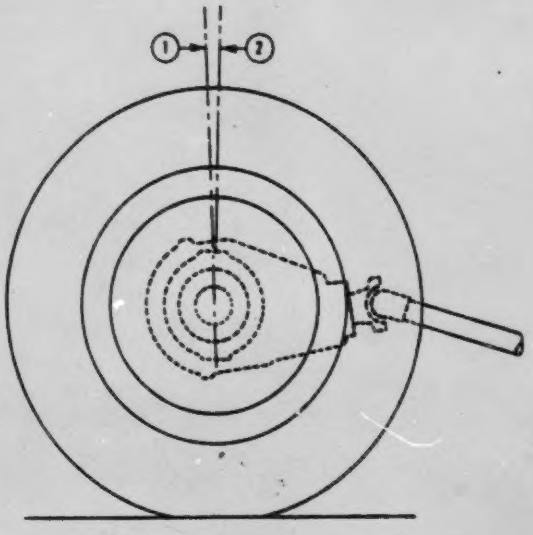
c. Inspect steering knuckle pivots, spindle, and wheel bearing looseness.

d. Check wheel runout.

e. Test wheel balance and bearing adjustment.

f. Check for spring sag.

g. Inspect brakes and shock absorbers.



1 Vertical line 2 Caster angle

Figure 14-4. Axle caster.

h. Check steering gear assembly adjustment and steering connecting rod.

i. Check caster.

j. Check toe-in.

k. Check toe-out on turns.

l. Check camber.

m. Check tracking of front and rear wheels.

n. Check frame alignment. The factors of alignment, caster, camber, and toe-in, are all interrelated and if one adjustment is made, another adjustment may be affected. Therefore, after an alignment job is completed, make a complete recheck of all the adjustments to be sure the ceilings are within the limit. Be sure all front suspension and steering system nuts and bolts are all properly torqued before taking wheel alignment readings.

14–7. Toe-In Adjustment

Note. Steering gear must be on the "high spot" when the wheels are in the "straight ahead" position.

To adjust the wheel toe-in, first raise the front of the vehicle to free the front wheels. Turn the wheels to the straight ahead position. Use as steady-rest to scribe a pencil line in the center of each tire tread as the wheel is turned by hand. A good way to do this is to first coat a strip with chalk around the circumference of the tread at the center forming a base for a fine pencil line.

Measure the distance between the scribed lines at the front and rear of the wheels using care that both measurements are made at an equal distance from the floor. The distance between the lines should be greater at the rear than the front by 3/32" to 5/32". To make adjustment to obtain this distance loosen the clamp bolts and turn the tie rod with a small pipe wrench. The tie rod is threaded with right and left hand wheels. Do not overlook retightening the clamp threads to provide equal adjustment at both bolts 12 to 15 lb-ft.

It is common practice to measure between the wheel rims. This is satisfactory providing the wheels run true. By scribing a line on the tire tread, measurement is taken between the road contact points which will reduce error of wheel run-out.

14–8. Camber Adjustment

Correct wheel camber of 1½° is set in the solid front axle at the time of manufacture, and cannot be altered by any adjustment. It is important that the camber is the same on both front wheels.

14–9. Caster Adjustment

The axle caster is preset at 3° and should be checked on a wheel alignment fixture. If found to be incorrect, correction may be made by either installing new parts or installing caster shims between the axle pad and the springs. If the camber and toe-in are correct and it is known that the axle is not twisted, a satisfactory check may be made by testing the vehicle on the road. Before road testing, make sure all tires are properly inflated, being particularly careful that both front tires are inflated to exactly the same pressure.

If vehicle turns easily to either side but returns hard to straight ahead position, incorrect caster is indicated. If correction is necessary, it can usually be accomplished by installing shims between the springs and axle pads to secure the desired result.

14–10. Front Wheel Shimmy

Wheel shimmy may be caused by various conditions in the wheels, axle, or steering system, or a combination of these conditions. Outlined below will be found the usual corrections of this fault:

a. Equalize the tire pressures.

b. Check the wheel bearings for looseness. Be sure that the inner wheel bearing race is not too loose on the spindle.

c. Remove both steering knuckles and carefully inspect the upper pivot pin bushings and lower pivot pin bearings. Inspect the bearing cups for evidence of brinelling, pitting, or fretting. Any bearings that show the slightest imperfection must be replaced. Adjust the pivot pin bearings. Reassemble and lubricate the front axle and steering linkage, *install new steering knuckle oil seals if present seals show any wear.*

d. Check wheel run-out. This check should include radial run-out and wheel looseness on the hub.

e. Check wheel balance. Check for blowout patches, uniform tire tread, vulcanized tires, mud on inside of wheels, and tires creeping on the rims.

f. Check for front spring sag on solid front axle vehicles. Also check for broken spring leaves, broken center spring bolt, loose spring clips (or tight clips), over-lubrication of spring leaves, spring shackle bracket loose on frame, and loose rear spring shackle. Be sure that the shock absorbers are operating properly to eliminate bobbing of the front end.

g. Check brakes to make sure that one does not drag.

h. Check the steering assembly and steering connecting rod. This includes the up and down play of the steering worm shaft, end play of the lever shaft, tightness of the steering gear to the frame, tightness of steering arm, adjustment of the steering connecting rod, and condition of the steering tie rod ball joint ends. Adjust the steering connecting rod (drag link) to maximum safe tightness at both ends.

i. Check front axle caster. This should be the same on both sides, otherwise a locking brake may be indicated causing a twisting action of the axle.

j. Check the front wheel toe-in.

k. Check wheel toe-out on turns. This gives an indication of the proper angularity of the steering knuckle arms and tells whether or not they have been bent and require replacing. These may be checked by comparing them with new parts. If an arm is bent, check for a bent tie rod.

l. Check wheel camber.

m. Check the steering axis inclination.

n. Check the tracking of the front axle and frame alignment, either of which may be out of alignment.

14–11. Steering Linkage Service

Refer to paragraphs 14–12 through 14–16.

14–12. Steering Connecting Rod

The steering connecting rod can be removed by removing the cotter pins and nuts from both ends, and then removing the rod. The steering connecting rod ball joints cannot be disassembled for service.

When installing the steering connecting rod, place the wheels in the straight ahead position and place the steering arm parallel to the centerline of the vehicle. Have the steering gear steering arm properly indexed, with line marks on the steering arm and gear shaft and the steering gear on center of high point. With the steering arm so positioned, install the connecting rod.

14–13. Tie Rod

The tie rod is of three-piece construction consisting of the rod (tube) and two ball and socket ends. Ball and socket ends are threaded into the rod and locked with clamps around each end of the rod (figure 14–1). Right and left-hand threads on tie rod ends provide toe-in adjustment without removing the tie rod ends from the steering arm.

14–14. Tie Rod Removal

The tie rod can be removed by removing the cotter pins and nuts at the ends. To remove the tie rod from the steering knuckle arms, use a puller or expansion fork. Then separate the joint seals and fittings, if necessary. The tie rod sockets can be removed by loosening the nuts on the clamp bolts and unscrewing the sockets from the tie rod tubes. When installing the components of the steering linkage, new seals should be installed as necessary. All nuts should be torqued 38 to 42 lb-ft.

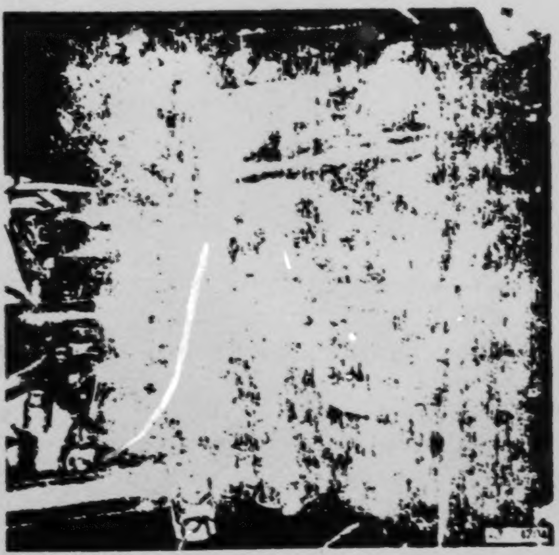


Figure 14–5. Steering gear.

14–15. Steering Gear

The steering gear must be removed from the vehicle in order to adjust it.

14–16. Removal of Steering Gear

a. Disconnect the steering gear from the steering column by removing the flexible coupling to gear Allen head clamping screw.

b. Disconnect the connecting rod from the steering arm.

c. Remove the three bolts attaching the steering gear to frame. Remove steering gear by sliding it slightly forward and to the right and lifting it out of the engine compartment.

14–17 Steering Gear Service

Refer to paragraphs 14–18 through 4–22.

14–18. Disassembly of Steering Gear

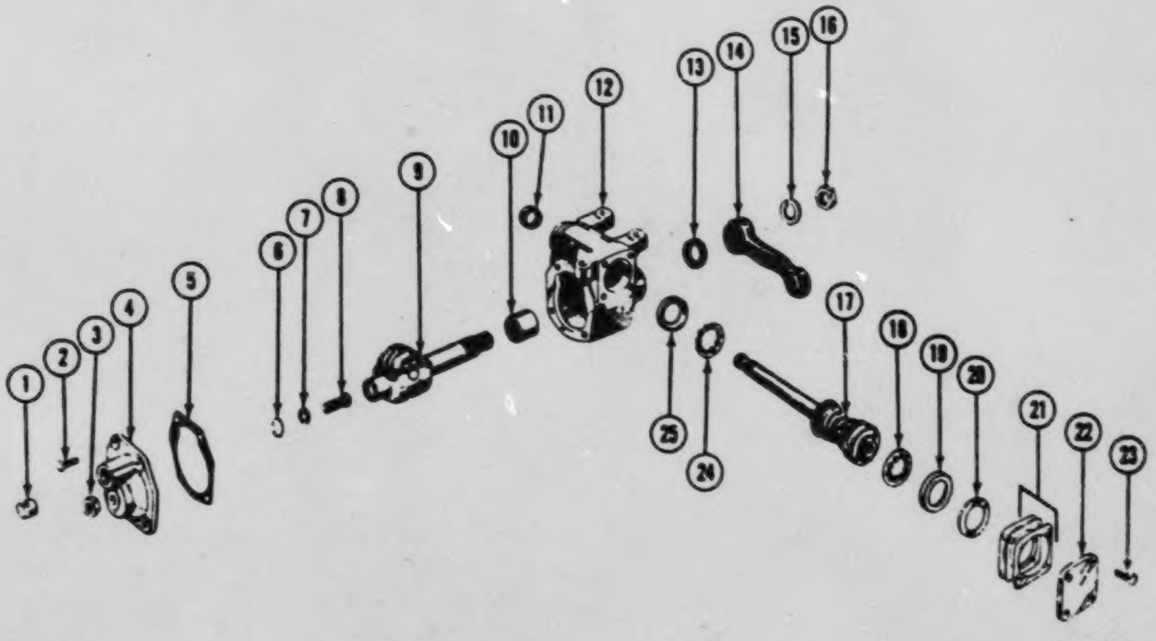
Refer to figures 14–5 and 14–6.

a. Clean the exterior of the steering gear. Remove filler plug from the steering gear housing and drain lubricant from the gear.

b. Make index marks on the roller gear and shaft assembly and on the steering arm, to assure correct alignment during assembly. Remove nut and lock washer from the shaft. Remove arm from the shaft with a steering arm puller or gear puller.

Caution: **Do not use a hammer or wedge to remove the steering arm from the roller gear and shaft assembly. This will damage the gear and shaft assembly.**

c. With a fine file or piece of emery cloth, remove any nicks or burrs from the exposed



1	Filler plug
2	Cap screw
3	Lock nut
4	Cover
5	Gasket
6	Retaining snap ring
7	Thrust washer
8	Adjustment screw
9	Roller gear and shaft assembly
10	Needle bearing
11	Oil seal
12	Steering gear housing
13	Oil seal
14	Steering arm
15	Lock washer
16	Nut
17	Worm gear and shaft assembly
18	Lower ball bearing race
19	Lower bearing cup
20	Thrust spacer
21	Shim
22	End cover
23	Cap screw
24	Upper ball bearing race
25	Upper bearing cup

Figure 14–6. Steering gear—exploded view.

portions of the roller gear and shaft assembly and from the worm gear and shaft assembly.

d. Remove four attaching cap screws, side cover, and gasket from the steering gear housing. When the cover is removed, the attached roller gear and shaft assembly will also be withdrawn from the housing.

e. Remove lock nut from the adjustment screw. Turn screw clockwise until it is completely unthreaded from the side cover; then remove the roller gear and shaft assembly from the cover.

f. Remove four attaching cap screws and the end cover from the steering gear housing. Withdraw worm gear and shaft assembly from the housing. Remove lower and upper bearing cups and ball bearings from the shaft.

g. Remove worm gear shaft oil seal and roller gear shaft oil seal from the housing. Discard both seals.

h. Clean all parts with suitable cleaning solvent and wipe dry.

i. Inspect the steering gear housing for cracks, breaks, leaks, or other damage. Replace if damaged.

j. Inspect the roller gear and shaft assembly visually for wear, scoring, or pitting. If necessary, polish lightly with a fine abrasive cloth. Inspect the roller gear to assure that it has proper freedom of movement and lacks excessive lash or roughness. Replace gear and shaft assembly if visibly worn or damaged.

k. Check adjustment screw of the roller gear and shaft assembly for excessive end play. If end play exceeds .015", remove the retaining ring, thrust washer, and screw from the gear and shaft assembly. Replace the retaining ring if unserviceable. Secure a new adjustment screw and thrust washer in the gear and shaft assembly with a retaining ring.

l. Inspect bearing surface in side cover and replace if visibly worn or damaged.

Inspect the worm gear and shaft assembly visually for wear, scoring, or pitting. If necessary, polish lightly with a fine abrasive cloth. Replace assembly if it is visibly worn or damaged.

Inspect upper and lower ball bearings and cups of the worm gear and shaft assembly for wear and damage. Replace if visibly worn or damaged.

Note. Bearing balls must be replaced as a full set in each bearing.

14–19. Assembly of Steering Gear

a. Position new oil seals at the worm gear shaft and roller gear shaft oil seal bores of the steering gear housing with the longer lip of each seal facing into the housing. Press each seal into the housing with a mandrel of suitable diameter to touch seal bore of the housing around its entire perimeter.

b. Lubricate worm gear and shaft assembly and the upper ball bearing and cup with SAE 90 gear oil. Install bearing and cup on the shaft. Install shaft assembly in the steering gear housing. Be certain that the splined end of the shaft does not damage the oil seal.

c. Lubricate lower end of the worm gear and shaft assembly and the lower ball bearing and cup with SAE 90 gear oil. Install bearing, cup, and spacer on the shaft. Position shims and end cover to the steering gear housing; attach loosely with four cap screws. Adjust bearing preload as described in paragraph 14–20.

d. Position tapped hole of the side cover to the adjustment screw of the roller gear and shaft assembly. Thread screw counterclockwise into the cover until the end of the shaft just touches the inner face of the cover. Install a lock nut loosely on the adjustment screw.

e. Install a new gasket on the side cover. Lubricate gear of the roller gear and shaft assembly with SAE 90 gear oil. Insert gear and shaft assembly into the steering gear housing. Be certain that the end of the shaft does not damage oil seal in the housing. Roller gear and worm gear must mesh to seat the side cover to the housing. Secure cover to the housing with four cap screws. Torque cap screws 18 to 22 lb-ft. Adjust gear clearance as described in paragraph 14–21.

f. Clamp exposed section of the roller gear and shaft assembly firmly in a soft-jaw vise. Observe index marks made during disassembly and position steering arm to splined end of the

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shaft. Install lockwasher and nut on shaft threads; tighten nut to draw arm into position on the spline.

g. Fill steering gear housing to the required level in car position with specified lubricant.

14–20. Steering Gear Bearing Preload Adjustment

This steering gear adjustment determines preload applied to upper and lower ball bearings, which support the worm gear and shaft assembly. It is made by adding to or subtracting from the number of shims between the steering gear housing and end cover, with the roller shaft assembly removed.

a. If necessary, loosen four cap screws which fasten the end cover to the steering gear housing.

Refer to figure 14–6.

b. Alternately tighten cap screws evenly, but only slightly at a time, and rotate the worm gear shaft. Torque screws 18 to 22 lb-ft.

c. Check rolling torque required to rotate the worm gear shaft. When bearing preload is correct, this torque will be 6 to 12 lb-in. If necessary, remove cap screws and end cover. Either add to, or subtract from, the number of shims, and repeat step *b*., above, to obtain correct bearing preload.

14–21. Steering Gear Clearance Adjustment

This steering gear adjustment sets proper backlash between the worm gear and the roller gear of the steering gear assembly. It prevents gear wear, and steering play which would result from excessive backlash. Gear backlash is adjusted by an adjustment screw, which determines the longitudinal position of the roller gear and shaft assembly.

a. If necessary, loosen lock nut and turn the adjustment screw at the side cover counterclockwise until the worm gear shaft turns freely throughout its entire range of travel. See figure 14–6.

b. Count the number of turns necessary to rotate the worm gear shaft through its entire range of travel. Turn shaft to center its travel. Rotate shaft back and forth through its center of travel, and tighten the adjustment screw until the shaft shows slight bind at the center of its travel. Adjust screw to obtain a rolling torque requirement of 15 to 29 lb-in. to rotate shaft through the center of travel. Hold adjustment screw in position and torque lock nut 16 to 20 lb-ft.

c. Recheck rolling torque necessary to rotate worm gear shaft through the center of its travel. If necessary, repeat *a* and *b* above, until this value of rolling torque is correct.

14–22. Installation of Steering Gear

a. After the gear has been properly adjusted, position the steering gear against the frame side rail, guiding the gear into the flexible coupling, and secure it in position with the attaching bolts. Align pointer on flexible coupling with line mark on gear input shaft.

b. Install the Allen head cap screw that holds the flexible coupling to the steering gear shaft. Torque Allen head screw 18 to 30 lb-ft.

c. Check gear to steering column alignment and adjust, if necessary, as described in paragraph 14–30.

d. Attach steering arm to connecting rod.

e. After the gear has been installed in the vehicle, the gear may have a slight roughness, running through 10 or 15 complete turn cycles.

14–23. Steering Column and Wheel Service

Refer to paragraphs 14–24 through 14–31.

14–24. Steering Wheel Removal

Refer to figure 14–7.

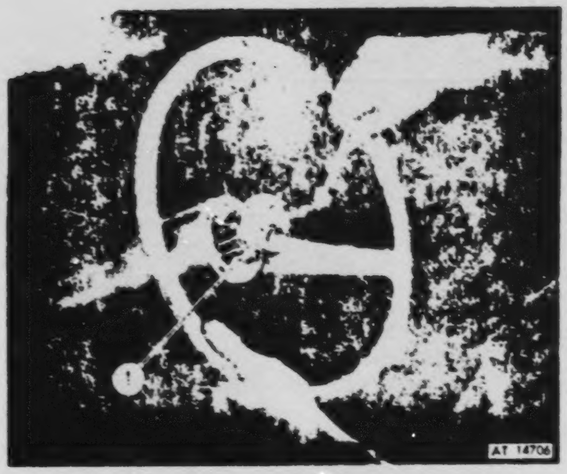
a. Carefully pry the horn cap from the housing slot in the lower end.

b. Remove three attaching screws in the wheel cavity. Remove housing, rubber boot, three insulators, and switch.

c. Remove steering shaft nut.

a. install puller and remove steering wheel and spring. See figure 14–7.

e. Examine wheel hub seal.



1 Puller

Figure 14–7. Steering wheel removal.

14–25. Steering Wheel Installation

Refer to figure 14–8.

a. Install steering wheel and spring on shaft. Align scribe marks on shaft and hub of wheel as shown in figure 14–8.

b. Install steering shaft nut and torque 20 to 25 lb-ft.

c. Position insulators to horn housing and switch. Install in steering wheel cavity. Install seal and secure with three screws.

Caution: **Exercise care in installing hub seal over column.**

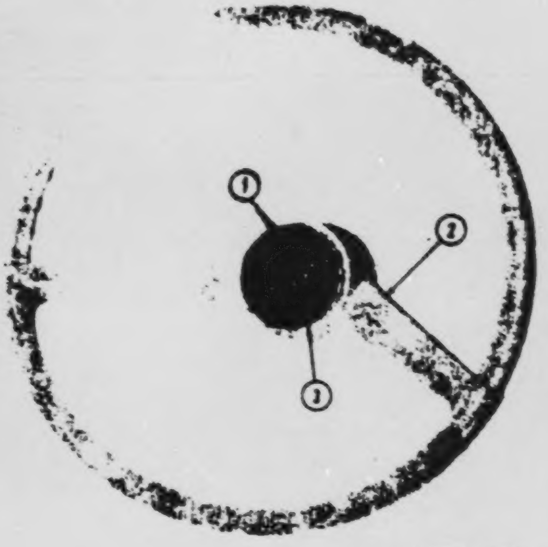
14–26. Steering U-Joint Coupling

Refer to figures 14–9 and 14–10.

The vehicle uses a two-piece steering shaft with the sections connected by a U-joint coupling at the steering column. The U-joint coupling has a single spring which is placed between two bearing blocks, tending to spread them apart and automatically take up the wear. When servicing the U-joint coupling, the following procedure should be followed:

a. Disconnect the lower steering shaft coupling at the steering gear by removing the two nuts, bolts and lock washers.

b. Loosen clamp holding U-joint coupling cover to lower shaft and remove U-joint coupling cover.



1 Alignment marks
2 Steering wheel
3 Steering shaft

Figure 14–8. Steering wheel and shaft alignment.

c. Remove spring clip from cover, and carefully remove cover from steering shaft. Use caution to avoid loss of small parts inside cover.

Note. Use extreme caution to prevent damage to bearing surfaces of the pin.

d. Remove steering shaft pivot pin bearing blocks and wave washers.

Inspection:

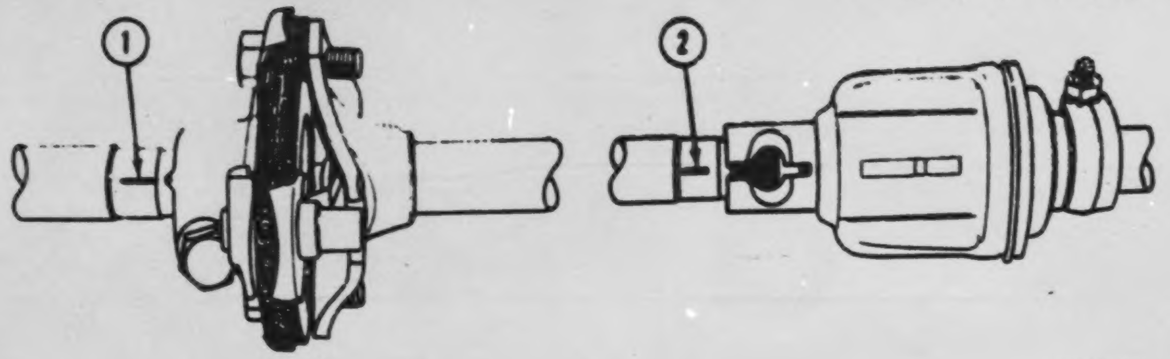
Carefully inspect all parts for signs of wear. If pivot pin in steering shaft is not serviceable, steering shaft must be removed and replaced with a new steering shaft-pin assembly.

Assembly:

a. Install coupling cover on lower shaft, aligning slot in clamp with mark on shaft. Install clamp bolt and tighten.

b. With steering shaft installed, place bearing blocks with wave washers in place over each end of pivot pin after first lubricating pin with chassis grease. Place retainer over end of shaft.

c. Lubricate inside of housing with chassis grease and carefully position over pivot pin.



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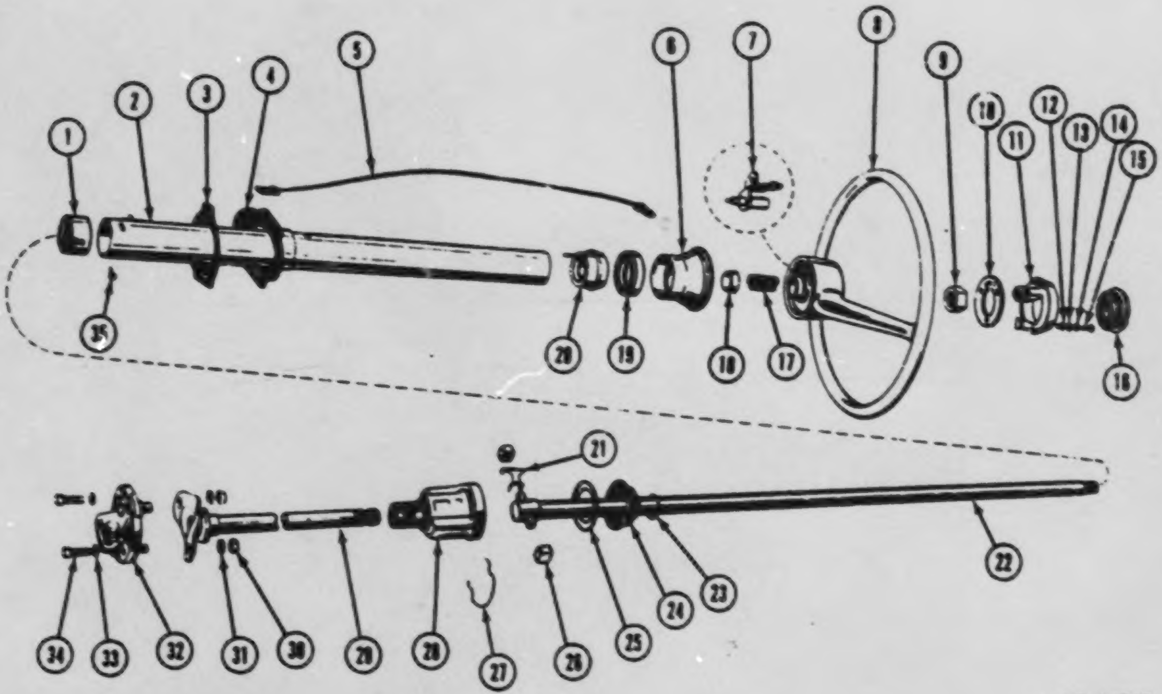
1 Flexible coupling to steering gear shaft
2 Lower shaft and flange to U-joint coupling

Figure 14-9. Steering shaft alignment marks.



AT 14709

1 Lower bearing
2 Outer tube assembly
3 Gasket
4 Support and clamp
5 Horn wire
6 Housing
7 Horn connector
8 Steering wheel
9 Nut
10 Horn switch
11 Horn button contact flange
12 Horn switch spacer
13 Flat washer
14 Lock washer
15 Screw
16 Horn button
17 Spring
18 Upper bearing collar
19 Seal
20 Upper bearing and horn connector
21 Spring
22 Upper steering shaft
23 Spring
24 Boot
25 Retainer
26 Bearing
27 Snap ring
28 Coupling housing
29 Low steering shaft and flange
30 Nut
31 Lock washer
32 Flexible coupling
33 Lockwasher
34 Cap screw
35 Screw and lockwasher

Figure 14-10. Steering column.

d. Position retainer and bolt in housing and install spring clip.

e. Connect lower shaft and flange to the flexible coupling attached to the steering gear. Install two bolts and tighten.

14–27. Steering Column Removal

a. Remove the flexible coupling to steering shaft bolts.

Note. The upper steering shaft is separated at the U-joint coupling by loosening or removing the U-joint coupling to lower shaft clamp. Refer to figure 14–10.

b. Disconnect the steering column wiring connector from the wiring harness underneath the instrument panel.

c. Fold the floor mat back and loosen seven steering column toe board cover plate attaching screws.

d. Remove toe board from lower column clamp by removing the two attaching bolts.

e. Remove upper steering column clamp attaching bolts underneath instrument panel, and remove steering column with lower column clamp and gasket, upper steering column clamp, and steering shaft and flange attached.

14–28. Steering Column Disassembly

a. After the steering column is removed from the vehicle, remove the center steering shaft from the steering column, and the shaft spacer from the flange housing.

b. Remove the two screws attaching the turn signal switch to the column and remove switch.

c. Disconnect horn wire contact and plate.

d. Disconnect the terminal from the steering column harness connector.

e. Pull the flange housing free of the column. Remove the spring washer from the flange.

f. Remove housing.

g. Remove upper bearing spacer.

h. Disconnect the lower nylon bearing attaching screws, and remove the bearing.

i. Inspect all parts for damage and wear and replace as necessary.

14–29. Steering Column Assembly

a. Install upper bearing spacer in steering column, as shown in figure 14–10.

b. If the column harness was removed, install the wiring in the column passage. Use a guide wire, and tape the end of the harness terminals, and guide the wire through the passage.

c. Position the housing on the column.

d. Install the flange by first installing the two bolts, nuts, and washers loosely in position on the flange. Then position the flange on the column aligning the heads of the bolts into the slots in the steering column. With the flange in this correct position, torque the two nuts to 45 to 55 inch-lb.

e. Position the lower column nylon bearing in lower end of steering column with screws.

f. Position and secure turn signal lever and switch.

g. Install horn wire contact and plate.

h. Install steering shaft and upper shaft spacer.

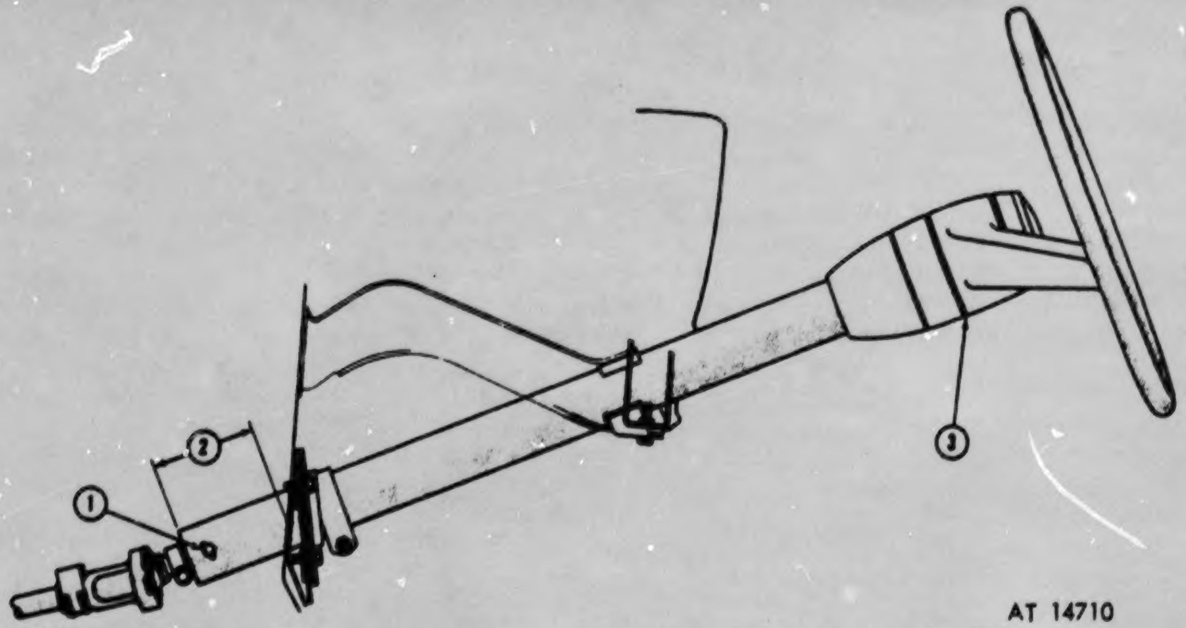
i. Connect flexible coupling to steering shaft.

j. If electrical harness was removed, replace terminals into connector in the same position as removed.

14–30. Steering Column Installation

a. Install upper end of lower shaft to the upper U-joint coupling. The split in the upper coupling clamp must be aligned to the mark on the upper end of the lower shaft to maintain steering wheel centering with steering gear hi-point. Secure attachment by tightening the upper coupling clamp. Install lower steering shaft and lower coupling assembly connecting lower coupling to wormshaft, with the cast pointer on the coupling aligned with the mark on the wormshaft as shown in figure 14–9. Secure coupling by installing two bolts, nuts and lockwashers.

b. Install the lower toe pan cover plate bolts.



1 Lower bearing adjusting screw
2 Measurement U-joint coupling position
3 Steering wheel to steering column gap

Figure 14–11. Steering column adjustments.

c. Check steering column alignment and adjustments.

d. Connect steering column connector into electrical harness.

14–31. Steering Column Adjustments

Refer to figure 14–11.

a. With the steering column, shaft, and U-joint coupling installed, and the front wheels set straight ahead, check position of mark on worm shaft designating steering gear high point. This mark should be at the top side of the shaft at 12 o'clock position and lined up with the mark in the flexible coupling lower clamp as shown in figure 14–9. If this alignment is correct, check the alignment of mark on upper end of lower steering shaft with saw cut in U-joint coupling. With the steering wheel installed be certain aligning mark on steering shaft matches with mark on steering wheel hub as shown on figure 14–8.

b. To insure proper U-joint coupling positioning, measure along side of the steering column and check dimension from bottom of column to the firewall face. The correct dimension is $3\frac{15}{16}''$. Refer to figure 14–11.

Should adjustment be necessary, loosen steering column clamps and move column up or down, until the proper measurement is obtained. Secure steering column by tightening all clamps.

c. Check the gap between the upper steering column housing and the steering wheel hub. To adjust gap, loosen the steering column shaft clamp (located above the U-joint coupling), and pull the steering column shaft upward. The proper clearance is $\frac{1}{16}''$ to $\frac{3}{32}''$. Refer to figure 14–11. Tighten clamp when the proper gap is obtained.

14–32. Trouble Shooting

Refer to paragraphs 14–33 and 14–34.

14–33. Hard Steering

Should hard steering be encountered, the following procedure should be followed:

First check tires for proper inflation. Then disconnect the steering arm and rotate the steering wheel. If the wheel turns freely with 1½ lb. of effort or less, reconnect the steering arm. If the wheel will not turn freely, first check for difficulty in the steering column as outlined in paragraph 14-31. If, after these adjustments, the wheel does not turn freely with the arm disconnected, proceed with the steering gear adjustments, as given in paragraphs 14–21.

If hard steering still exists after the above checks, check front wheel alignments (paragraphs 14-6, 14-10), and front axle steering knuckle bearing preload. The front axle steering knuckle bearing preload scale readings should be taken at the the rod socket tapered hole in the steering kunckle arm, with joint seal and axle shafts removed. Take the scale readings when the knuckle has just started its sweep. The steering knuckle bearing preload should be 12 to 16 lb. with the oil seal removed.

14–34. Service Diagnosis

Symptoms	*Probable remedy*
Hard Steering:	
Lack of lubrication	Lubricate all connections
Tie rod ends worn	Replace
Connecting rod ball joints tight	Adjust
Cross shaft improperly adjusted	Adjust
Steering gear parts worn	Replace
Frozen steering shaft bearings	Replace bearings
Lower coupling flange rubbing against steering shaft	Loosen bolt and assemble properly
Steering wheel rubbing against gearshift bowl	Adjust jacket endwise
Steering gear or connections adjustment too tight	Check adjustment by dropping pitman arm from gear or disconnecting linkage from pitman arm ball. Readjust if necessary.
Front spring sagged	Check front end jounce height. Jounce height should be approximately the same at both wheels. Compare dimensions with those on car having about same mileage and equipment and believed to be standard. Replace front springs if sagged.
Frame bent or broken	Repair frame as necessary
Steering knuckle bent	Install new knuckle
Low or uneven tire pressure	Inflate tires to recommended pressure

14–35. Steering Specifications

Steering gear:	
Make	Gemmer
Type	Worm and roller
Ratio	24 to 1
Bearings:	
Cam—Upper	Ball
Cam—Lower	Ball
Lever shaft	Roller
Steering column upper	Bushing
Worm preload w/seals	6–12 in.-lb.
Worm preload over center w/seals	15–29 in.-lbs
Wheel diameter	16–17 in.
Steering geometry:	
King-pin inclination	8"
Toe-In	3/32" to 5/32"
Camber	1½°
Caster	3°
Turning radius	28"
Turning angle	29°

BRAKES

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12-1. General

The vehicle is equipped with hydraulic brakes. The hydraulic brake system is shown in figure 12-1. All vehicles are equipped with a lever type, hand operated parking brake, that operates in the drive line, at the rear of the transfer case.

This section covers all the maintenance and service requirements for parking and hydraulic brakes.

12-2. Hydraulic Brake System

Refer to figure 12-2. Action by the brake pedal moves the master cylinder piston which exerts pressure on the fluid in the cylinder and lines.

The master cylinder primary cup is held against the piston by the piston return spring. The return spring also holds the check valve against the valve seat. The spring maintains a slight fluid pressure in the lines and in the wheel cylinders to prevent the possible entrance of air into the system.

The secondary cup, which is secured at the opposite end of the piston, prevents leakage of fluid into the rubber boot. The holes in the piston head allow the fluid to flow from the space in back of the piston into the space between the primary cup and the check valve, keeping sufficient fluid in the lines at all times.

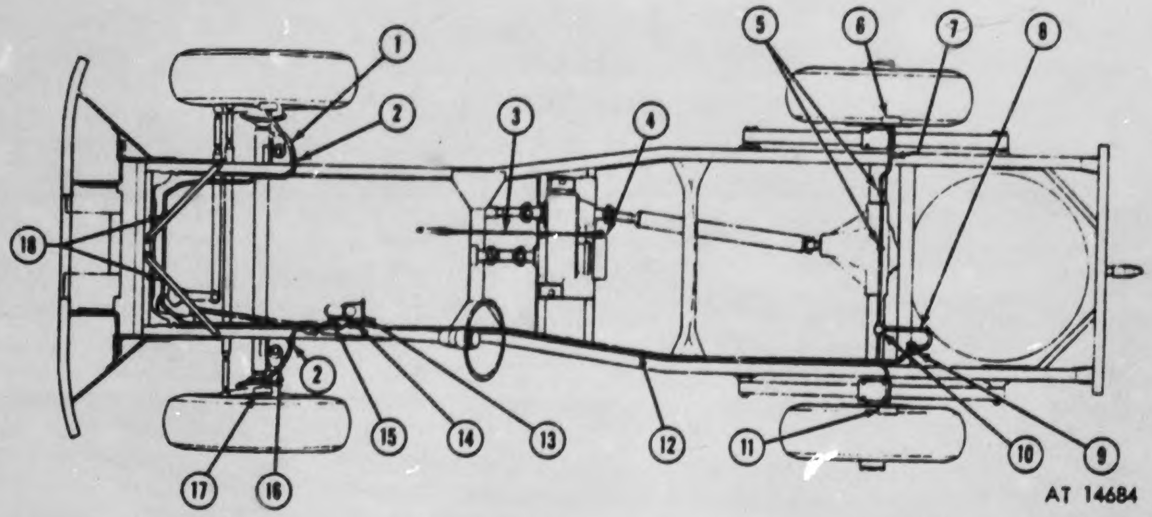
The holes in the check valve case allow the fluid to flow through the case around the lips of the rubber valve cup and out into the lines during the brake application. When the brakes are released, the valve is forced off the seat permitting the fluid to return to the master cylinder. The piston assembly is held in the opposite end of the housing by means of a piston stop snap ring. The rubber boot fits around the push rod and over the end of the housing to prevent dirt from entering the master cylinder.

The wheel cylinders, figure 12-3 are double piston cylinders. The purpose of the two pistons is to distribute the pressure evenly to each of the two brake shoes.

Rubber cylinder cups on the pistons prevent the leakage of fluid. The rubber boots over the end of the cylinder prevent dust from entering the cylinder.

When pressure is applied to the brake pedal, the master cylinder forces pressure through the lines and into the wheel cylinders. This pressure forces the pistons in the wheel cylinders outward, expanding the brake shoes against the drums. As the pedal is further depressed, higher pressure in the hydraulic system causes the brake shoes to exert greater force against the brake drums.

As the brake pedal is released, the hydraulic pressure is released and the brake shoe return spring pulls the shoes together, drawing the wheel cylinder pistons inward and forcing the fluid out of the cylinders back into the lines toward the master cylinder. In the master cylinder, the piston return spring returns the piston to the piston stop snap ring faster than the



1 Front brake tube to right wheel cylinder flexible line
2 Clamp
3 Parking brake control rod
4 Parking brake
5 Brake tube clips
6 Right rear wheel cylinder
7 Rear brake tube tee to right wheel cylinder tube
8 Flexible line to rear brake tube tee
9 Brake tube clip
10 Rear brake tube tee
11 Left rear wheel cylinder
12 Rear brake tube
13 Master cylinder
14 Front brake tube tee
15 Front brake tube to clamp
16 Front brake tube to left front wheel cylinder flexible line
17 Left front wheel cylinder
18 Brake tube clip

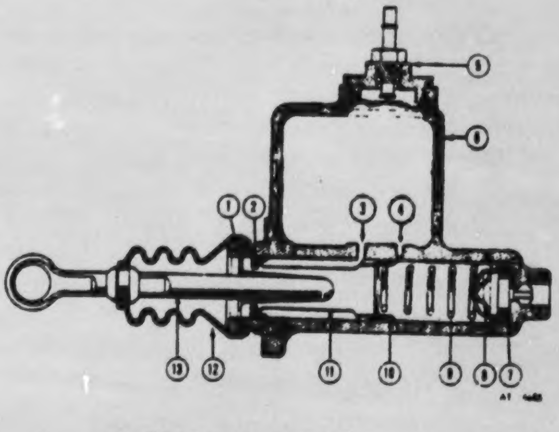
Figure 12-1. Brake system.

brake fluid is forced back into the master cylinder, which creates a slight vacuum on the head of the piston. The vacuum causes a small amount of fluid to flow through the holes of the piston head, past the lip of the primary cup, and into the forward part of the cylinder. This action keeps the cylinder filled with fluid at all times, ready for the next brake application.

As fluid is drawn from the space behind the piston head, it is replenished from the reservoir through the intake port. When the piston is in fully released position, the primary cup clears the by-pass port, allowing the excess fluid to flow from the cylinder into the reservoir as the shoe retracting springs in all cylinders continue to force the fluid back into the lines and master cylinder.

12-3. Parking (Transmission) Brake

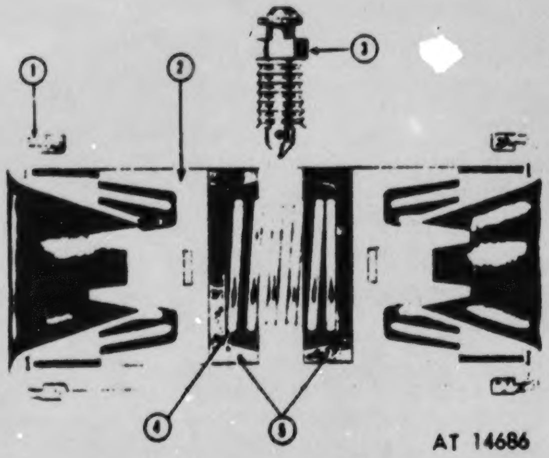
The parking brake lever is operated by hand and has a push-button release. When the lever is pulled, tension is exerted on the parking brake rod leading to the parking brake (which is mounted at the rear of the transfer case) causing the brake shoe to press against the



1 Piston stop snap ring
2 Secondary cup
3 Intake port
4 By-Pass port
5 Vented fill cap
6 Supply tank
7 Valve seat
8 Check valve
9 Return spring
10 Master cylinder primary cup
11 Piston
12 Boot
13 Push rod

Figure 12-2. Brake master cylinder.

drum. The amount of brake grip that can be applied increases by the number of notches the brake lever is pulled. To disengage the parking brake, depress the button on top of the lever. Refer to figures 12–4 and 12–5.



1 Cylinder boot
2 Piston
3 Bleeder screw
4 Cup spring
5 Cylinder cup

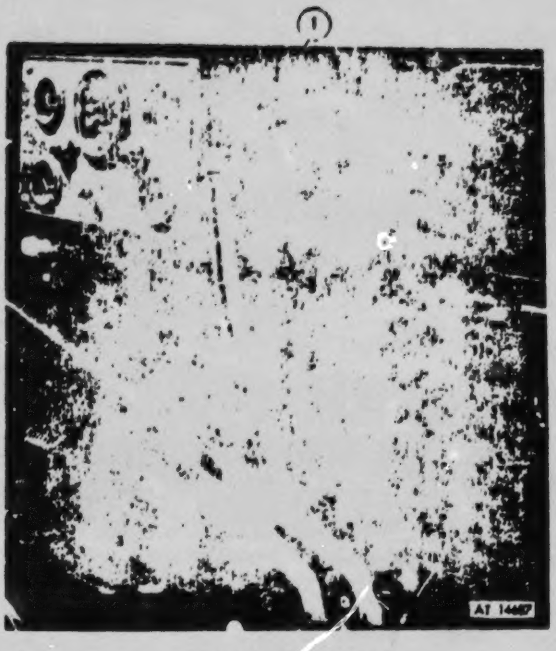
Figure 12–3. Brake wheel cylinder.

12–4. Brake Maintenance

No brake can be expected to work well when grease or oil is allowed to leak into the drum from the rear axle. Little braking friction can be obtained between brakes and drums when the surface is covered with grease and oil. For this reason, take care not to over-lubricate wheel bearings, forcing lubricant past seals. Also, check condition of seals if leak is suspected or whenever brake drums are pulled.

Whenever wheels are removed, it is advisable to wash the drums with a suitable solvent so that all grease and dirt are removed. Linings with any evidence of grease or oil on them should be replaced. The hydraulic system should be kept free of dirt and moisture. It is advisable to drain the system and flush with pure alcohol once a year.

Caution: **Keep mineral oils, gasoline, or kerosene out of the system as they cause rubber cups to soften, swell, and distort resulting in failure.**



1 Parking brake control

Figure 12–4. Parking brake controls.

12–5. Brake Service

To service the hydraulic brake system, follow the procedure below:

a. Check the fluid level in the brake master cylinder.

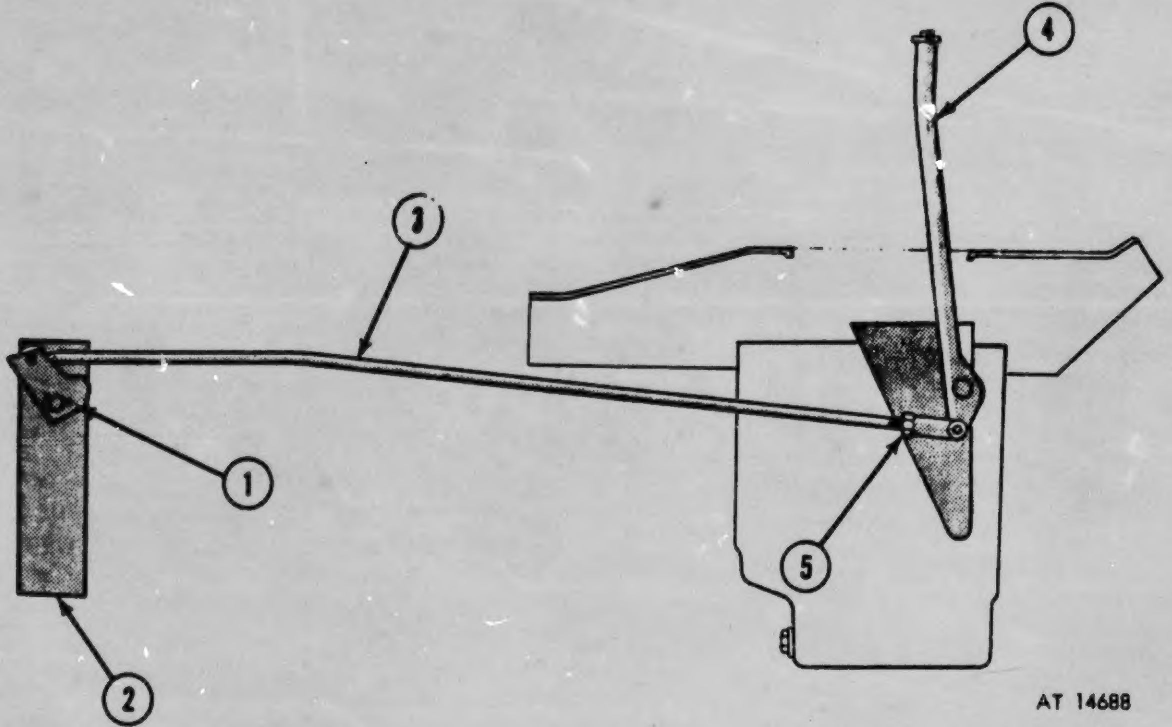
b. Check brake pedal adjustment. See paragraph 12–6.

c. Check brake pedal travel. If the pedal travels more than halfway to the floor, the brakes may need adjusting to compensate for lining wear or they may need relining. How much lining is left can only be determined by visually inspecting the linings.

See paragraph 12–8 for brake adjustment; paragraph 12–13 for relining brakes.

d. If the brakes pull to one side after adjustment, check tire pressures. All tires must be inflated to recommended pressures to ensure even braking. If the condition persists, examine the brake linings for foreign material and replace linings if necessary. If the side pull persists, check front wheel alignment and balance.

e. Check the brake system for leaks by



1 Operating cam
2 Brake shoe and lining
3 Operating rod
4 Parking brake handle
5 Adjusting nut

Figure 12-5. Parking brake linkage.

applying a steady pressure on the brake pedal. A leak in the system will allow the pedal to "fall away." If the pedal "falls away" check for a leaking wheel cylinder. Remove wheels and drums and carefully check each cylinder. Also examine all lines and fittings. Replace all wheel cylinders (para 12-12) if one is defective, as they are all probably in poor condition. If the leak has allowed brake fluid to get on the linings, the lining will have to be replaced.

f. A "spongy" brake pedal indicates the presence of air in the hydraulic system. This condition must be corrected by bleeding the brakes. See paragraph 12-10.

g. Should the brakes become locked so that the vehicle cannot be moved, the brakes may be released by opening the bleeder screw on any one of the wheel cylinders. Before the vehicle is driven, correct the cause of the condition. The cause may be either a defective master cylinder or low grade brake fluid which has expanded because of heat.

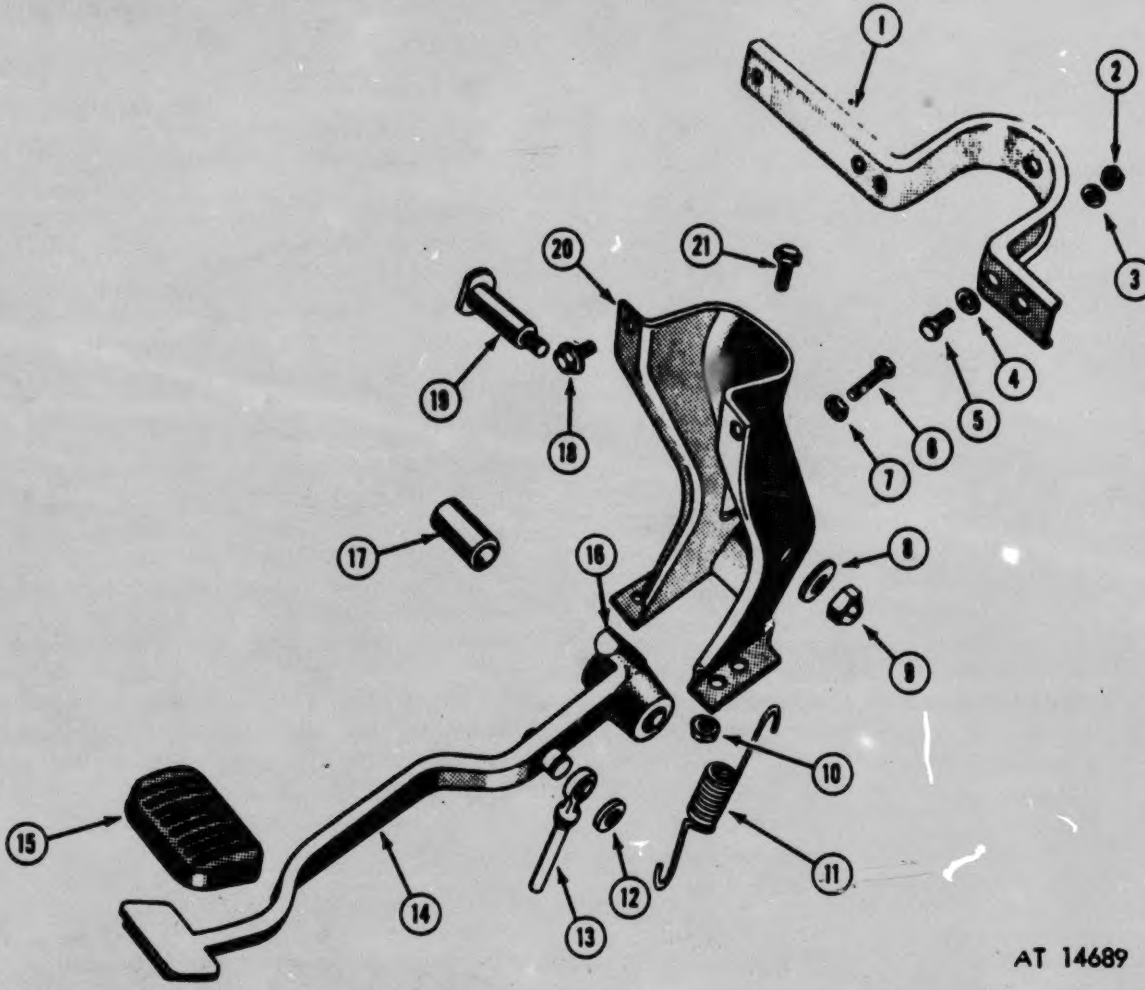
12-6. Brake Pedal Adjustment

There should always be at least ½" free pedal travel before the push rod engages the master cylinder piston.

This adjustment is accomplished at the brake mounting bracket.

To adjust free pedal travel, first loosen the adjusting bolt locknut. Turning the adjusting bolt in (clockwise) decreases the amount of free pedal travel, turning the adjusting bolt out (counterclockwise) increases the amount of free pedal travel.

Too great a free pedal travel prevents the push rod from bottoming against the master cylinder piston, giving excessive pedal travel *before* brake application. Not enough free pedal travel will prevent the primary cup in the mas-



1 Brace
2 Nut
3 Lockwasher
4 Flat washer
5 Bolt
6 Adjusting bolt
7 Locknut

8 Flat washer
9 Nut
10 Nut and washer assembly
11 Retracting spring
12 Washer
13 Master cylinder push rod
14 Brake pedal

15 Brake pedal pad
16 Brake pedal bumper
17 Bushing
18 Capscrew
19 Brake pedal shaft
20 Brake pedal mounting bracket
21 Bolt

Figure 12-6. Brake pedal, mounting and adjusting parts.

ter cylinder from clearing the by-pass port when the piston is in the released position. This will destroy the compensating action of the master cylinder for expansion and contraction of the fluid in the system due to temperature changes.

12-7. Handbrake Adjustments

a. Adjust Handbrake Band.

(1) Place the vehicle on a level floor and place the handbrake in the fully released position.

(2) Remove the cotter pin and clevis pin that attach the control rod to the cam levers.

(3) Remove the locking wire from the anchor screw.

(4) Loosen the two jamnuts on the adjusting J-bolt and the two jamnuts on the adjusting screw.

(5) Insert a 0.015-inch thickness gage be-

tween the brake lining and the drum at the anchor clip. Turn the anchor screw as required until slight friction is felt as the gage is withdrawn.

(6) Insert the thickness gage between brake lining and drum above J-bolt and turn the upper nut on the adjusting J-bolt as required to establish the same clearance as above.

(7) Insert the thickness gage between brake lining and drum below J-bolt, hold the adjusting screw, and turn the lower nut on the adjusting screw as required to establish the same clearance as above.

(8) Check the clearance between the lining and the drum at several points. Clearance should be approximately 0.015 inch at all points.

(9) When the adjustment has been completed, tighten the jamnuts on the adjusting J-bolt and the adjusting screw. Secure the anchor screw with locking wire, attaching the wire to the bracket in such a manner that it will not interfere with the anchor screw spring.

(10) Adjust the handbrake control rod before connecting it to the cam levers.

b. Adjust Handbrake Control Rod.

(1) With the brake control rod detached from the cam levers, loosen the nut at the yoke end of the brake control rod and turn the rod in the yoke until the eye of the rod is in alignment with the clevis pin holes in the two cam levers.

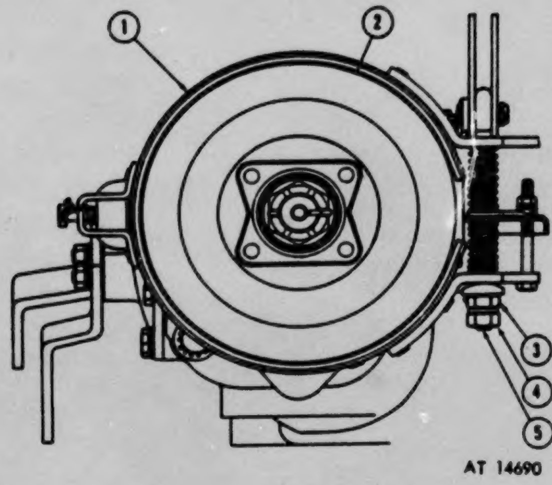
(2) Attach the control rod to the cam levers with the clevis pin and cotter pin.

(3) Tighten the nut against the yoke.

Note. With the brake band and control rod properly adjusted, the pawl should be engaged in the third to fifth notch of the sector for full application of the brake.

12–8. Brake Adjustment

When the brake linings become worn, effective brake pedal travel is reduced. Adjusting the brake shoes will restore the necessary travel. Before adjusting the brakes, check the spring clip nuts, brake dust shield to axle flange bolts, and wheel bearing adjustments. Any looseness in these parts will cause erratic brake seizure. Also check that the brake pedal has ½" free travel without moving the master cylinder piston.



1 Brake band
2 Brake drum
3 Adjustment nut
4 Lock nut
5 Bolt

Figure 12–7. Transmission band type brake adjustment.

1 Adjusting tool

Figure 12–8. Brake shoe adjustment.

Centralize the brake shoes in the drums by depressing the brake pedal hard and then releasing it. Since the brakes are of the self-centering type, they require no anchor adjustments. Hoist all four wheels off the ground and adjust the brakes according to the procedures given in paragraph 12-9.

12-9. Brake Adjustment (Star Wheel)

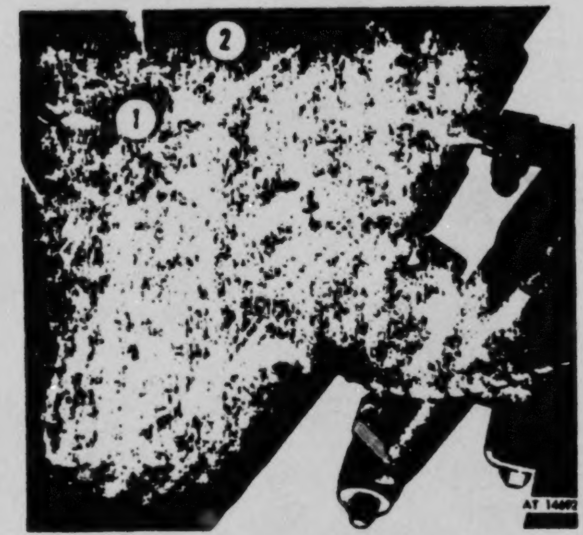
Adjust the brakes as follows:

a. Remove the adjusting hole dust clip from the back of the brake backing plate. See figure 12-8.

b. Use Brake Adjusting Tool to turn the star wheel. Raise the handle of the tool to tighten the shoes against the drum.

c. When the brake shoes are tight against the drum, turn the star wheel in the opposite direction until the vehicle wheel just rotates freely without brake drag.

d. Repeat the above procedure for all four wheels.



1 Brake hose 2 Bleeder screw

Figure 12-9. Bleeding brakes.

12-10. Bleeding Brakes

The hydraulic brake system must be bled whenever a fluid line has been disconnected or air gets into the system. A leak in the system may sometimes be indicated by the presence of a spongy brake pedal. Air trapped in the system is compressible and does not permit the pressure applied to the brake pedal to be transmitted solidly through to the brakes. The system must be absolutely free from air at all times. During the bleeding operation, the master cylinder must be kept at least ¾ full of hydraulic brake fluid. When using pressure type brake bleeder, follow manufacturer's instructions. To bleed the brakes follow this procedure:

First, carefully clean all dirt from around the master cylinder filler plug. Remove the filler plug and fill the master cylinder to the lower edge of filler neck. Clean off all bleeder connections at all four wheel cylinders. Attach bleeder hose and fixture to wheel cylinder bleeder screw and place end of tube in a glass jar and submerge in brake fluid.

Note. Bleed at that wheel with the longest line from the master cylinder first, the next longest second, etc.

Open the bleeder valve half to three-quarters of a turn. See figure 12-9.

Depress the foot pedal, allowing it to return very slowly. Continue this pumping action to force the fluid through the line and out of the bleeder hose which carries with it any air in the system. When bubbles cease to appear at the end of the bleeder hose, close the bleeder valve and remove the hose. After the bleeding operation at each wheel cylinder has been completed, fill the master cylinder reservoir and replace the filler plug.

Discard the liquid which has been removed from the lines through the bleeding process because of air bubbles and dirt.

12-11. Brake Hoses

a. Hydraulic lines (tubing and hose) are the means of transmitting fluid under pressure between the master cylinder and the wheel cylinders. The hoses are the flexible links between the wheels or axles and the frame or body. The hoses must withstand the fluid pressures without expansion and must be free to flex during spring deflection and wheel turns without causing damage to the hose.

b. Hydraulic lines are subject to damage and deterioration. Hoses should be inspected for cuts, chafing, cracks, twists and loose frame supports. Hydraulic tubing should be inspected for signs of leakage (due to faulty flares or loose connections); restrictions (due to dents or corrosion); wear (due to friction against other metal parts). Always use correct type and size of wrench on fittings. Avoid damage to female fittings by supporting fitting with tube nut during removal of assembly.

c. On fittings where gaskets are used, always use a new gasket. Copper gaskets take a set and may not form a good seal if reused.

d. When replacing hydraulic brake hose, attach hose to wheel cylinder and securely tighten hose, then attach opposite end to frame fitting or tubing. Avoid twists in hose when assembling to frame fitting or tubing. Hold hose end securely with wrench while attaching tubing to hose. If hose end clip is used, make certain clip is assembled properly. Check for interference during spring deflection or rebound and during front wheel turns.

e. Check for any possible contact between front brake hose and inner sidewall of tire when the front wheels are in maximum turn position. Check for sufficient but not excessive length of hose between the clamp and the wheels by turning the wheels from one extreme turn position to the other.

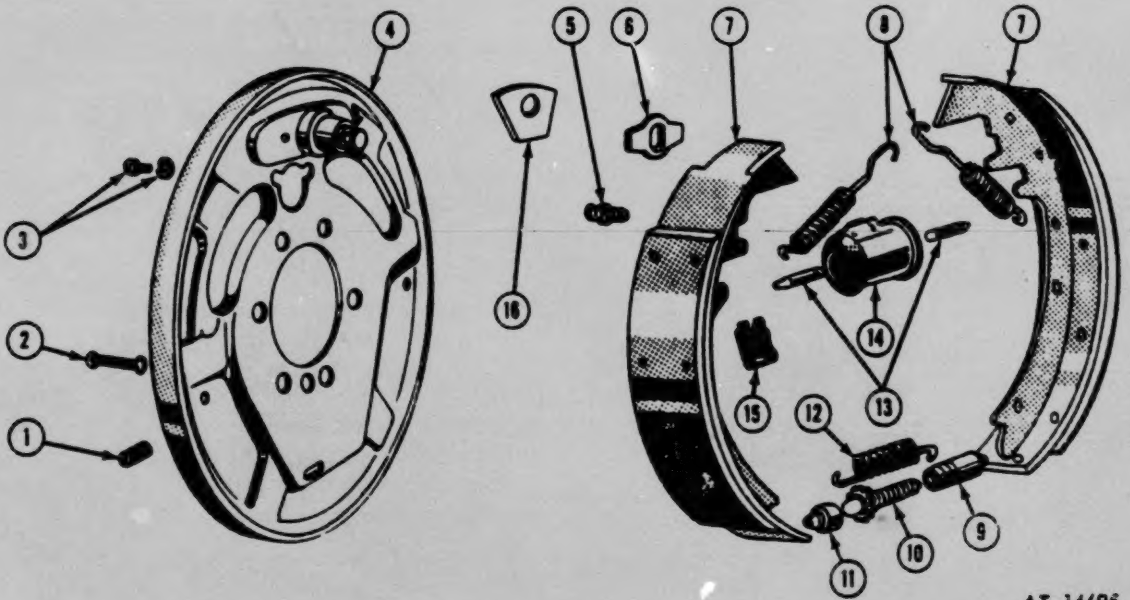
f. Check that there is no possibility of any contact between the tail pipe and rear brake hose under all operating conditions.

12-12. Wheel Cylinder

Refer to figure 12-10.

Note. Make sure a replacement brake cylinder has the same part number as the original cylinder.

a. To remove a wheel cylinder, jack up the vehicle and remove the wheel, hub, and drum. Disconnect the brake line at the fitting on the brake backing plate. Remove the brake shoe return spring which will allow the brake shoes at the toe to fall clear of the brake cylinder. Remove two screws holding the wheel cylinder to the backing plate.



1 Adjusting hole cover
2 Hold down pin
3 Lockwasher and cap screw
4 Backing plate
5 Bleeder screw
6 Anchor pin washer
7 Brake shoe
8 Return spring
9 Adjusting screw socket
10 Adjusting screw
11 Adjusting screw socket
12 Return spring
13 Push rod
14 Wheel cylinder
15 Hold down spring
16 Self-centering anchor block

Figure 12-10. Front wheel servo brake (star wheel adjustment).

b. Install wheel cylinder to the backing plate and connect brake line and install brake shoe return spring.

c. Replace wheel, hub, and drum.

d. Bleed the brake lines (para 12–10).

e. Adjust brakes if required (para 12–8).

12–13. Relining Wheel Brakes

a. When necessary to reline the brakes, the vehicle should be raised so that all four wheels are free.

b. Turn the star wheel adjustment all the way in.

c. Remove the wheels and drums which will give access to the brake shoes figure 12–10.

d. Install Wheel Cylinder Clamps to retain the wheel cylinder pistons in place and prevent leakage of brake fluid while replacing the shoes.

e. Remove the brake shoe return springs.

Note. Brake shoes may be distored by improper lining installation and linings should be ground true after installation on the shoes. For this reason it is recommended that new or replacement shoe and lining assemblies be installed.

Note. When handling brake shoes, do not permit oil or grease to come in contact with the brake linings.

f. Install anchor block with convex surface contacting the primary shoe and the straight side contacting the secondary shoe. The arrow stamped on the anchor block must always be installed pointing in the direction of forward wheel rotation. Install the brake shoes on the brake backing plates. Remove the wheel.

Note. When installing the brake shoe return springs, always install the primary (front) shoe spring first.

g. Install the hold down pins and the brake shoe retaining spring clips.

Note. Using brake drum micrometer check all drums. Should a brake drum be rough and scored, it may be reconditioned by grinding or turning in a lathe. Do not remove more than .030" thickness of metal, .060" overall diameter. If a drum is reconditioned in this manner, either the correct factory-supplied, oversize lining .030" must be installed, or a shim equal in thickness to the metal removed must be placed between the lining and shoe so that the arc of the lining will be the same as that of the drum.

h. Install the drums and make a major adjustment of the brakes.

Note. If it is found when wheels are removed that there is brake fluid leakage at any of the wheel cylinders, it will be necessary to replace or the wheel cylinder (para 12–12) and bleed the brake lines (para 12–10).

Whenever the brake lining is replaced in one front or one rear wheel, be sure to perform the same operation in the opposite front or rear wheel, usually the same braking lining part number. Otherwise, unequal brake action will result.

12–14. Parking Brake Band, Cam Levers, and Spacer Link

a. Removal.

(1) Disconnect the brake rod from the brake cam lever.

(2) Remove 3-inch screw from lining assembly and cast bracket.

(3) Cut brake band anchor lock wire and remove brake band anchor clip screw, taking care not to lose brake band anchor spring located inside the bracket.

(4) Remove two brake adjusting nuts from brake adjusting bolt. At this point, loosen the two bolts holding the ends of the rear transfer case cross member until the cross member drops approximately ½".

(5) Lift brake adjusting bolt upwards until it clears the lower ear of the brake shoe assembly and remove the bottom spring.

(6) Continue to lift the brake adjusting bolt and pull the brake shoe assembly rearward at the same time until the brake band bolt clears the cast retainer. Brake shoe assembly is now off.

(7) If the adjusting J-bolt, cam levers or spacer link requires replacement, remove the cotter pin and clevis pin that attach the two levers and the spacer link to the J-bolt. If the spacer link stud in the brake support requires replacement, remove the nut, lockwasher, and stud.

b. Inspection.

(1) Clean the parts that were removed and the brakedrum.

(2) Inspect the cam levers and link spa-

cer for cracks, distortion, and elongated clevis pin holes.

(3) Inspect the adjusting J-bolt, adjusting screw, anchor screw, and spacer link stud for cracks and damaged threads.

(4) Inspect all springs for cracks, distortion and weakness.

(5) Inspect the drum for scoring or cracks. Report a damaged drum to ordnance maintenance personnel.

(6) Replace all parts that are unfit for further service.

c. Installation.

(1) If the spacer link stud was removed, install the stud in the brake support and install the lockwasher and nut. Tighten the nut.

(2) Assemble the adjusting J-bolt and related parts with a cam lever at each side of the bolt and the spacer link next to the left lever, aligning the clevis pin holes in the link and two levers with the eye in the adjusting J-bolt. Install the cam lever clevis pin and cotter pin.

(3) Position the anchor screw spring in the anchor clip on the band and install the band on the brake support. Install the anchor screw but do not tighten at this time.

(4) Position an adjusting bolt spring at each side of the brake support between the support and the band ends, and install the adjusting J-bolt and attached cam levers and spacer link, inserting the bolt through the band ends, two springs, and brake support. Install the plain washer and two jamnuts on the lower end of the bolt, but do not tighten at this time.

(5) Attach the front end of the spacer link to the spacer link stud and install the cotter pin.

(6) Install the adjusting screw up through the band lower end and the brake support and install the lockwasher and two jamnuts. Do not tighten the nuts at this time.

(7) Raise transfer case cross member and tighten attaching bolts.

(8) Adjust the band and control rod (para 12-7).

12-15. Troubleshooting

Refer to paragraphs 12-16 and 12-17.

12-16. Squeaky Brakes

In many cases, brake squeak can be eliminated by correct adjustment of the brakes. Squeaks may be caused however, by glazed linings, linings worn thin to the point of exposed metal or by vibration. A drum will not vibrate when the brake is securing uniform contact over the entire lining surface except when due to improper conditions such as the linings becoming glazed. Glazed surface of the brake linings is cause for replacement of the linings. Occasionally squeaks are caused by roughened surface of the drum, which can usually be remedied by rubbing with emery cloth and by wiping the braking surface clean. In extreme cases it may be necessary to reface the drum in a lathe. Should this be done, do not remove a metal thickness greater than .030" or .060" over all diameter.

12-17. Rattles in Brakes

See that the tension of the springs in the brakes and attached to the control system is sufficient to return brakes and brake mechanism to their normal position. Return springs are so placed that they keep all slack out of the control system by tension on all joints.

Brakes will not rattle inside the drum if the springs holding the shoes are kept at the proper tension.

12-18. Service Diagnosis

Symptoms	*Probable remedy*
Brakes drag:	
Brake shoes improperly adjusted	Readjust
Piston cups—enlarged	Flush all lines with alcohol—install new cups in wheel and master cylinders
Mineral oil or improper brake fluid in system	
Improper pedal adjustment	Adjust brake pedal height
Clogged master cylinder compensating port	Clean master cylinder
One brake drags:	
Brake shoe adjustment incorrect	Adjust

Symptoms	Probable remedy
Brake hose clogged	Replace
Return spring broken or weak	Replace
Wheel cylinder piston or cups defective	Replace
Loose or damaged wheel bearings	Adjust or replace
Brake grabs—vehicle pulls to one side:	
Grease or brake fluid on lining	Replace lining
Dirt between lining and drum	Clean with wire brush
Drum scored or rough	Turn drum and replace lining—shim lining
Loose wheel bearing	Adjust
Axle spring clips loose	Tighten
Brake backing plate loose	Tighten
Brake lining	Different kinds on opposite wheels
Brake shoe reversed	Forward and reverse shoes reversed in one wheel
Tire under-inflated	Inflate
Tires worn unequally	Replace or change around to opposite wheels
Glazed or worn lining	Replace linings
Restricted brake line	Locate and repair
Excessive pedal travel:	
Normal lining wear	Adjust
Lining worn out	Replace
Leak in brake line	Locate and repair
Scored brake drums	Replace or regrind—shim lining
Incorrect brake lining	Replace
Air in hydraulic system	Fill master cylinder and bleed brakes
Spongy brake pedal:	
Air in lines	Bleed lines
Brake shoe adjustment incorrect	Adjust
Insufficient brake fluid	Fill master cylinder
Excessive pedal pressure:	
Grease or brake fluid in lining	Replace lining
Shoes improperly adjusted	Major adjustment
Warped brake shoes	Replace
Distorted brake drums	Replace or regrind—shim lining
Glazed or worn lining	Replace linings
Restricted brake line	Locate and repair
Faulty brake cylinder	Repair or replace
Insufficient brake fluid	Fill master cylinder
Squeaky brakes:	
Brake shoes warped or drums distorted	Replace
Lining loose	Replace
Dirt imbedded in lining	Clean with wire brush or replace
Improper adjustment	Adjust
Oil or grease on lining	Replace linings
Glazed or worn lining	Replace linings
Drum scored	Turn drum and replace linings

12-19. Brake Specifications

Drum diameter:	
Front	13"
Rear	13"
Lining size:	
Front shoe:	
Front wheel	13" x 2 1/2" x 1/4"
Rear wheel	13" x 2 1/2" x 1/4"
Rear shoe:	
Front wheel	13" x 2 1/2" x 1/4"
Rear wheel	13" x 2 1/2" x 1/4"

Wheel cylinder bore:	
Front	1 1/16"
Rear	1 1/16"
Master cylinder bore	1"
Pedal free play	1/2"
Rear propeller shaft:	
Parking brake:	
Type	External
Drum diameter	7.84"
Lining size	7 31/32" x 2" x 1/4"

LUBRICATION AND PERIODIC SERVICES

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B-1. General

The M175 and M725 Vehicles require periodic lubrication and other maintenance services to promote satisfactory operation, and prevent excessive wear. Under severe operating or atmospheric conditions, the vehicle may require these services more often than suggested in the maintenance operation schedules. It should be pointed out that common short trip, stop-and-go driving is the most severe usage which is further intensified during cold weather. In direct contrast, constant speed driving on highways is less severe. The specified types and amounts of lubricants given in the lubrication chart and text of this section should be closely followed. The lubrication notes for operations under unusual conditions given in the last part of this section, should be followed when applicable.

B-2. Special Lubricants

MIL lubricants are lubricants that carry the military specification number they conform to. Standard brands that meet with the "MIL SPEC" are in many cases marked on the container with this number.

B-3. Applying Fresh Lubricant

When lubricating all lubrication points, it is important that all the old lubricant be removed. To assure this, force lubricant through the lube fittings until the lubricant being forced out of the joint is fresh lubricant, indicating that all old lubricant has been removed. When applying lubricant to the propeller shaft splines, clean and liberally apply lubricant with a clean brush.

B-4. Engine Lubrication System

The engine is lubricated through a full-pressure lubrication system (fig. B-1) that uses a progressing tooth gear oil pump driven by a helical gear on the crankshaft. Oil is drawn to the pump through a fixed intake screen that strains out the larger impurities in the oil supply. From the oil pump, the full flow of oil is directed through the oil filter where smaller particles are filtered out. The oil is then ported through passages in the block to supply lubrication to the main bearings. Oil passages in the crankshaft mate with the oil grooves in the main bearings, then these passages conduct the oil to the crankpin bearings in the connecting rods. Spurt holes in the connecting rods provide lubrication to the cylinder walls.

A passage in the block conducts oil to a fitting at the front of the block to provide a stream of oil to the timing chain, sprocket, and oil pump drive gear. An external hose at the rear of the engine connects the oil passage in the block to an oil passage in the cylinder head. Oil to the cylinder head is ported to the rear camshaft bearing and through passages in the camshaft to provide lubrication to the cam lobes. A passage in the cam bearing deck provides oil to each of the remaining camshaft bearings. Oil drips from a small projection in the rocker arm cover to lubricate the fuel pump eccentric. A tube is provided in the oil passage of the cam bearing deck to deliver the oil under pressure to the front of the bearing deck to make sure that oil does not drain back when the engine is stopped. This system provides immediate lubrication to the cam bearings when the engine is restarted. Ports are provided between the cylinder head and the crankcase and also between the timing chain cover area and the crankcase to allow the oil to flow back to the oil pan for recirculation.

B-5. Chassis Lubrication

The chassis should be serviced at periodic intervals. Most chassis lubricating points have standard lubrication fittings. Refer to the Lubrication Diagram and Chart for specific points and lubricating time intervals. It is not necessary to disassemble prepacked joints to lubricate them. Merely add new lubricant, as described in paragraph B-8, to remove all old lubricant.

At the appropriate interval, clean each lubrication fitting indicated on the Lubrication Chart. Use a pressure gun to lubricate. Be sure the grease channels are open to provide complete lubrication of bearing surfaces. In some cases it may be necessary to disassemble to clear plugged channels.

B-6. Lubrication Intervals

Perform the following operations at the intervals shown.

Intervals	Lubrication service
Daily	Para B-7
Annually	Para B-8
1,000	Para B-9
6,000	Para B-10
12,000	Para B-12

When vehicles are driven primarily in abnormally dusty or wet areas or when subjected to severe operating conditions, perform these services more frequently. Under these conditions no definite interval can be recommended because of the great variety of uses and conditions of use.

B-7. Lubrication Service (Daily)

Crankcase—Check Crankcase level.

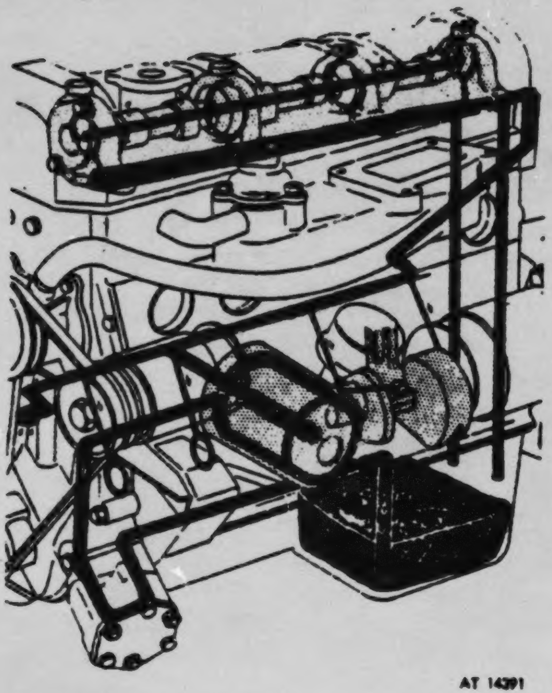

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Figure B-1. Engine lubrication system.

B-8. Lubrication Service (Annually)

Winch Worm Case—Drain and refill
Winch Drum and Shaft Case—Drain and refill

B-9. Lubrication Service (1,000 Miles)

The following points must be lubricated and serviced every 1,000 Miles of vehicle operation:

Steering Links
Universal Joint and Steering Knuckle Housing
Steering Tie Rod Sockets
Clutch Release Cross Shaft
Brake Master Cylinder—Note: Fill to ½ in. from top,
Universal and Slip Joints
Pintle Hook
Spring Shackle (Rear)
Spring Bolt (Rear)

B-10. Lubrication Service (6,000 Miles)

The crankcase must be drained and oil filter replaced every 6,000 miles of vehicle operation.

Every 6,000 miles of vehicle operation remove ignitor cap and lubricate the wick, breaker arm and breaker arm pivot. Service air cleaner.

B-11. Lubrication Service (12,000 Miles)

Front and Rear Wheel Bearings—Remove, Clean, Dry and Repack.
Rear Differential—Drain and refill
Transfer Case—Drain and refill
Transmission—Drain and refill
Front Differential—Drain and refill
Steering Gear—Drain and refill

B-12. Initial Lubrication

When a new vehicle is placed in service or after the engine has been overhauled, the engine oil must be changed and the oil filter replaced after the first 500 miles of operation, and then every 6,000 miles of normal highway driving. Under more severe service, change the oil more often. Common short trip, stop-and-go driving is the most severe and is further intensified during cold weather. In contrast, constant-speed driving on the highway is the least severe. The oil filter shoul be replaced each 6,000 miles of normal driving.

B-13. General Procedures for all Services and Inspections

a. The following general procedures apply to organizational preventive-maintenance services and to all inspections, and are just as important as the specific procedures.

b. Inspections to see if items are in good condition, correctly assembled or stored, secure, not excessively worn, not leaking, and adequately lubricated apply to most items in the preventive-maintenance and inspection procedures. Any or all of these checks that are pertinent to any item (including supporting, attaching, or connecting members) will be performed automatically, as general procedures, in addition to any specific procedures given.

(1) Inspection for good condition is usually visual inspection to determine if the unit is safe or serviceable. Good condition is explained further as meaning: Not bent or twisted, not chafed or burned, not broken or

cracked, not bare or frayed, not dented or collapsed, not torn or cut, not deteriorated.

(2) Inspection of a unit to see if it is correctly assembled or stored is usually a visual inspection to see if the unit is in its normal position in the vehicle and if all its parts are present and in their correct relative position.

(3) Excessibely worn is understood to mean worn beyond serviceable limits or likely to fail, if not replaced before the next scheduled inspection. Excessive wear of mating parts or linkage connections is usually evidenced by too much play (lash or lost motion). It includes illegibility as applied to markings, data and caution plates, and printed matter.

c. Where the instruction "tighten" appears in the procedures, it means tighten with a wrench, even if the item appears to be secure.

d. Such expressions as "adjust if necessary" or "replace if necessary" are not used in the specific procedures. It is understood that whenever inspection reveals the need of adjustments, repairs, or replacements, the necessary action will be taken.

e. Any special cleaning instructions required for specific mechanisms or parts are contained in the pertinent section. General instructions are as follows:

(1) Use drycleaning solvent or mineral spirits paint thinner to clean or wash grease or oil from all parts of the vehicle.

(2) A solution of one part grease-cleaning compound to four parts of drycleaning solvent or mineral spirits paint thinner may be used for dissolving grease and oil from engine block, chassis, and other parts. Use cold water to rinse off any solution which remains after cleaning.

(3) After the parts are cleaned, rinse and dry them thoroughly. Apply a light grade of oil to all polished metal surfaces to prevent rusting.

(4) When authorized to install new parts, remove any preservative materials such as rust-preventive compound, protective grease etc; prepare parts as required (oil seals etc.); and for those parts requiring lubrication, apply the lubricant prescribed in the lubrication order.

Note: **Steam cleaning will not be performed by organizational maintenance personnel.**

f. General precautions in cleaning are as follows:

(1) Drycleaning solvent or mineral spirits thinner is flammable and should not be used near an open flame. Fire extinguishers should be provided when this material is used. Use only in well ventilated places. Battery ground should be disconnected and taped.

(2) This cleaner evaporates quickly and has a drying effect on the skin. If used without gloves, it may cause cracks in the skin and, in the case on some individuals, a mild irritation or inflammation.

(3) Avoid getting petroleum products, such as drycleaning solvent or mineral spirits paint thinner, engine fuels, or lubricants on rubber parts as they will deteriorate the rubber.

Warning: **The use of diesel fuel oil, gasoline or benzene (benzol) for cleaning is prohibited.**

g. Nameplates, caution plates, and instruction plates made of steel, rust rapidly. When plates are found in a rusty condition, they should be thoroughly cleaned and heavily coated with an application of clear lacquer.

B–14. General Procedures for Organizational Maintenance

a. Automatically Applied. All of the general procedures previously listed herein will be followed. Organizational mechanics must be so thoroughly trained in these procedures that they will apply them in the performance of their duties.

b. Operator's Participation. The driver or crew usually accompanies the vehicle and assists the organizational mechanics in the performance of organizational maintenance services.

c. Unwashed Vehicles. The driver or crew should present the vehicle for a scheduled preventive-maintenance service in a reasonably clean condition; that is, it should be dry and not caked with mud to such an extent as to seriously hamper inspection and services. However, washing of the vehicle should be avoided immediately prior to an inspection, since certain types of defects such as loose parts and oil leaks may not be evident immediately after washing.

d. Services. Organizational maintenance services are defined by and restricted to general procedures unless approval has been given by the direct support maintenance organization.

(1) *Adjust.* Make all necessary adjustments in accordance with instructions contained in the pertinent section of this manual, information contained in changes to the subject publication, or technical bulletins.

(2) *Clean.* Clean the unit to remove old lubricant, dirt, and other foreign material.

(3) *Special lubrication.* This applies either to lubrication operations that do not appear on the lubrication order, or to items that do appear but which should be performed in connection with the maintenance operations, if parts have to be disassembled for inspection or service.

(4) *Service.* This usually consists of performing special operations, such as replenishing battery water, draining and refilling units with oil, and changing and cleaning the oil filter, air cleaner or cartridges.

(5) *Tighten.* All tightening operations should be performed with sufficient wrench torque (force on the wrench handle) to tighten the unit according to good mechanical practice. Use a torque-indicating wrench where specified. Do not over tighten as this may strip threads or cause distortion. Tightening will always be understood to include the correct installation of lockwashers, locknuts, locking wire, or cotter pins to secure the tightened nut.

(6) *Modification work order application.* Enter all modification work orders (MWO) applicable to the equipment on DA Form 2408–5, upon receipt of the MWO, regardless of the category of maintenance responsible for applying it.

e. Special Conditions. When conditions make it difficult to perform the complete preventive-maintenance procedures at one time, they can sometimes be handled in sections. Plan to complete all operations within the week if possible. All available time at halts and in bivouac areas must be utilized, if necessary, to assure that maintenance operations are completed.

B–15. Semiannual "S" Preventive-Maintenance Services

a. Purpose. The "S" preventive-maintenance services insure the correct adjustment, securing, and assembly of all components of the materiel. Necessary replacement, cleaning, lubrication, and protection of parts and/or assemblies will be accomplished as required, to give reasonable assurance of trouble-for operation until the next "S" preventive-maintenance service is performed.

b. Intervals. The semiannual "S" preventive-maintenance services are performed by the organizational mechanics every 6 months or at every 6,000 miles of vehicle operation, whichever occurs first. Under unusual conditions, temporary deviation from the prescribed service or interval may be authorized at the direction of the commander. The commander will consult with the direct support maintenance officer prior to a decision to deviate from these services.

B–16. Specific Procedures for Organizational Maintenance

Specific procedures for performing each item in the semiannual 'S" preventive-maintenance services on the materiel are given in table 1, using DA Form 2404 as a worksheet, in accordance with procedures outlined. Results of inspection and checking during preventive-maintenance services is authorization to take corrective action by performing the service or repair by organizational maintenance personnel. If repairs by a higher category of maintenance are required, DA Form 2407 (Maintenance Request) will be prepared and forwarded with equipment to the supporting maintenance activity.

Sequence No.	Items to be inspected	Procedure
		PRIOR TO ROAD TEST
		Note. When tactical situation does not permit a full road test, perform only those items that require little or no movement of the vehicle.
1	Oil and coolant	Check oil and coolant levels. Check spare containers for contents.
2	Water Pump, fan, belts, and pulleys.	Inspect pulleys and fan for alinement. Check water pump for leaks. Check fan and alternator drive belts tension. Provide 50 to 60 lb. tension. If belt tension gauge is not available, belt tension of ½" deflection may be obtained by applying a light thumb pressure midway between alternator and water pump pulley.
3	Electrical wiring	Visually inspect electrical wiring, conduits, connectors and shielding.
4	Engine compartment	Inspect engine compartment for indications of fuel, engine oil, and water leaks. Look under the vehicle for indications of leaking gear oil or brake fluid.
5	Tires	Note any apparent loss of air. Remove penetrating objects such as nails or glass. Note unusual wear or missing valve caps. Gage tires for correct pressure, as specified.
6	Fire extinguisher	Visually inspect fire extinguisher (on vehicle so equipped). Note if fire extinguisher is charged and sealed.
7	Tools and equipment	Inspect vehicle tools and equipment (including vehicle publications) for general conditions and proper stowage.
8	Vehicle body	Check for any tampering or damage that may have occurred since last inspection.
9	Steering gear and controls.	Check steering system and component parts for loose or damaged parts.
10	Cab: doors, glass, top, frame, curtains, fasteners, straps.	Inspect these items, paying particular attention to cab, body mountings, including springs. Test operation of doors, windows, windshield, hood-hinges, and fasteners. Observe seat mountings and upholstery. Inspect litter racks and operation of personnel heater (Ambulance Truck M725). Make a general inspection of body, including glass, panels, tops, fenders, tailgate, chains, stakes, bows, paulins, curtains, radiator, and lamp guards. Examine condition of paint and legibility of markings, and identification and caution plates.
11	Lights, horn, windshield wipers, blowers, and heater.	Operate horn and windshield wipers. Inspect rear view mirrors. Check operation of exterior lights and light switches. Note whether the headlights appear to be properly aimed. Note condition of all lights and reflectors. Test the spotlight switch and handle for proper operation (Ambulance Truck M725). Test operation of surgical light, dome light, blowers, and heater (Ambulance Truck M725).
12	Brake pedal	Check service brake pedal for proper travel and handbrake linkage for proper adjustment (correct service brake pedal free travel is ½-inch).
		ROAD TEST
13	Instruments-functional check.	Prior to starting engine, turn ignition switch on and observe instrument operation. Battery alternotor indicator should indicate alternator is not charging--pointer in yellow band. Fuel quantity gage should move to indicate fuel tank level. Oil pressure gage should indicate 0 psi and water temperature gage should move from an off scale reading to actual coolant temperature reading.
14	Starter and switch	Note if the starter switch requires more than normal pressure, and if the starter engages smoothly without unusual noise, and turns the wire with adequate cranking speed. With ignitior switch on, start engine.
15	Instrument operational check.	Note alternator output on charge indicator immediately after starting engine before alternator regulator has reduced the charging wire to serve all instruments for normal readings. Note what is the ignition switch and light switch levers operate freely and make possible contact. Check all other instruments for normal operation.

Table I. Preventive Maintenance Checks and Service—Continued

Sequence No.	Items to be inspected	Procedure
16	Engine operation	In warming up engine, observe if choke operates satisfactorily. Note if idling speed is 600 to 650 rpm. Listen for and unusual noise at idle and higher speeds. When operating vehicle, note if it has normal power and acceleration in each speed range. Listen for any unusual noises when the engine is under load. Speed up vehicle, on a level stretch, to see if it will reach, but not exceed, the specified top speed.
17	Alternator	Observe charge indicator to note whether alternator is charging properly. Listen for unusual noises.
18	Clutch	Note if the clutch pedal has one (1) inch free travel and if action of pedal return spring is satisfactory. Note whether clutch disengages completely or has a tendency to drag. Observe smoothness of engagement and tendency to chatter, grab, slip, or any unusual noise. With transmission in neutral, depress and release clutch pedal listening for noises indicating a defective release bearing.
19	Transmission and transfer.	Shift transmission into all speeds and transfer into high and low ranges, observing any unusual stiffness of shift levers, tendency to slip out of gear, unusual noises, or excessive vibration. Make similar observations of the transfer clutch lever.
20	Service and parking brake (handbrake) operation.	Note if action of brake return spring is satisfactory. Observe if pedal goes too close to floor. Make several stops, noting side pull, noise, chatter, grabbing, or any other abnormal condition. Observe if the handbrake lever ratchet holds and if the lever requires more than three-quarters travel for full application. (With the brake band and control rod properly adjusted, the pawl should be engaged in the third to fifth notch of the sector for full application of the brake). Stop vehicle on an incline and apply handbrake to determine if it holds vehicle.
21	Steering system	With vehicle moving straight ahead, determine if there is any tendency to wander, shimmy or pull to one side. Turn steering wheel through its entire range and note any binding. At all times during road test, be alert for unusual noises that may indicate looseness, defects, or deficient lubrication at any point.
22	Power train, wheels, and body.	At all times during road test, be alert for unusual noises that may indicate looseness, defects, or deficient lubrication at any point.
		AFTER ROAD TEST
23	Hub, drums, axles, powertrain.	Immediately after the road test, feel these units cautiously. ***Warning:*** Full floating hypoid axles operate quite hot. If lubrication levels are correct and no unusual noises occurred during road test, assume axles are functioning properly. Do not touch hypoid axles with bare hand after vehicle has been operated a considerable distance, serious burns may result. An overheated wheel hub and brake drum indicates an improperly adjusted, defective or dry wheel bearing or a dragging brake. An abnormally cool condition indicates an inoperative brake. An overheated gear case indicates lack of lubrication, gears out of adjustment, or defective parts.
24	Battery-specific gravity	Make hydrometer test of electrolyte in each cell of both batteries (1.275–1.300 at 80° F.) and record readings on DA Form 2404.
25	Battery voltage	Perform starting motor cranking voltage test (24v) using test meter. Record voltage registered on DA Form 2404. On vehicles so equipped, check insulator on positive (+) post of the inside battery between cover and terminal.
26	Battery terminals, carrier, and fluid level.	Clean cable terminals and battery posts. Clean top of battery. Clean and paint carrier as required. Install cables to battery and coat terminals lightly with grease. Check electrolyte level to determine if it covers plates. *NOTE.* If distilled water is not available, clean water, preferably rain water, may be used.

Table 1. Preventive Maintenance Checks and Service—Continued

Sequence No.	Items to be inspected	Procedure
27	Spark Plugs	Remove and inspect plugs. Clean and set at gap 0.030 inch. Replace if necessary.
28	Compression test	With engine at normal operating temperature, throttle and choke open, test compression of each cylinder. Record readings on DA Form 2404.
29	Ignition components	Test operation of advance mechanism by hand. Test ignitor shaft for looseness. Replace breaker points if required, adjust gap 0.020 inch. Replace other ignition component as required.
30	Carburetor, choke, linkage.	Inspect these items, noticing particularly if the shafts and linkage operate freely and are not excessively worn. Observe if the choke valve opens fully.
31	Carburetor, fuel pump, timing, and alternator regulator.	Perform an engine vacuum test and adjust carburetor. Be sure fuel pump is between 4 and 5½ psi at idling speed. Check the ignition timing with timing light for correct timing and proper advance (5° BTDC). Test alternator regulator with low voltage circuit tester.
32	Fuel filter engine compartment.	If vehicle is so equipped, clean fuel filter sediment bowl, if required.
33	Manifolds and heat control.	Inspect these items. Look particularly for leakage signs at the manifold gaskets. Check manifold heat control valve seasonal adjustment.
34	Vehicle exhaust system and fuel burning personnel heater.	Inspect entire vehicle exhaust system for excessive noise and leaks. Tighten mountings. On ambulance truck operate patient's compartment heater and inspect heater exhaust system for leaks and proper operation. Pay special attention to body floor and side panels for leaks.
35	Crankcase ventilation	Inspect carburetor air cleaner and air cleaner elbow and the crankcase ventilation metering valve for cleanliness and condition. On vehicles so equipped, inspect operation of the ventilation shutoff valve dual control. Replace air cleaner cartridge if plugged and lack of engine power is noticed.
36	Radiator and cap	Inspect these items, noting particularly if the radiator core is obstructed by foreign matter or if the core fins are bent. Check gasket in the pressure cap. Observe coolant level and examine coolant for contamination. Test coolant with hydrometer to see if it contains sufficient antifreeze to correspond with seasonal requirements. Tighten radiator hose clamps and mounting bolts. If need is indicated, drain cooling system, clean and fill, adding corrosion inhibitor unless antifreeze, which contains inhibitor, is used.
37	Fuel tank strainer and filter.	Clean strainer in the fuel tank filler pipe. Clean fuel filter in fuel tank (as equipped). If excessive contamination is noted in the fuel tank filter or in the sediment bowl of the engine compartment fuel filter (as equipped), drain water and sediment from fuel tank using a container to catch draining. Also, check fuel filter line at fuel tank cover for looseness on fuel tank filter equipped vehicles. Tighten nut securely.
38	Bumpers, pintles and shackles.	Bumpers, front and rear, pintle, and lifting shackles will be inspected. Check operation of pintle assembly and note whether it locks securely.
39	Power take-off, winch	Inspect power take-off, winch drive shaft, and shear pin. Inspect winch cable. Test winch operation. Check if vent in the worm housing is clear.
40	Winch cable	Clean and lubricate winch cable in accordance with current lubrication order (LO 9-2320-244-12).
41	Propeller shaft and U-joints.	Inspect propeller shaft assemblies. Tighten universal joint companion flange nuts, wheel and drum flange stud nuts.
42	Vents and leaks	Make observation under vehicle for evidence of oil, water, hydraulic fluid, or lubricant leaks. Inspect if vents in front and rear axles, transfer, and steering gear housing are clear.
43	Brake shoes, lining, anchor pins, springs.	Test brake linkages for freedom of action. Examine brake drums, shoes anchor pins and supports. Check wheel cylinders for leakage. Check operation of master cylinder.

Table 1. Preventive Maintenance Checks and Service—Continued

Sequence No.	Items to be inspected	Procedure
44	Wheel bearings	Disassemble, clean, and pack wheel bearings as directed by current lubrication order.
45	Tires	Rotate and inspect tires according to tread design and degree of wear. Refer to TM 9-1870-1 for acceptable limits in matching tires. Tighten axle drive flange nuts.
46	Springs and shock absorbers.	Inspect springs, shackles, shock absorbers, and attaching parts for damage and breakage.
47	Body and frame	Tighten body holddown bolts.
48	Clean	Wash vehicle, clean inside of cab, glass, and mirror. Clean engine and engine compartment as required. Do not steam clean.
49	Lubricate	Lubricate vehicle in accordance with intervals as specified in current lubrication order.
50	Fuel	Fill fuel tank as necessary.
51	Test	Final road test vehicle and particularly observe items which required repair, replacement, or adjustment.

B-17. General Lubrication and Preventive Maintenance Instructions

Items included in paragraphs B-7 through B-12 should be lubricated and serviced at the specified interval under normal operating conditions. However, under severe operating or atmospheric conditions, these operations should be performed at more frequent intervals.

B-18. Engine Oil

It may be necessary to change engine oil more frequently than normally recommended, depending upon the type and quality of oil used, the severity of operation conditions, if the engine is used for short periods in cold weather, or if the engine is allowed to idle for excessive periods.

Always drain the crankcase while the engine is hot since dirt and contaminants are then more likely to be held in suspension and therefore will drain out more completely. Drain the crankcase as follows:

a. Position the drain receptacle under the drain plug.

b. Remove the drain plug using the correct size wrench. Be careful of hot oil.

c. Carefully clean the drain plug. Inspect and replace the gasket, if deteriorated.

d. When the oil has drained, replace and tighten the crankcase drain plug.

e. Check for the presence of excess water in the oil that might indicate an internal leak from the cooling system.

f. Pour oil into the oil filler tube on the top of the rocker arm cover. Replace the oil filler cap.

B-19. Engine Oil Filter

The oil filter should be replaced at 500 miles and, thereafter, at every scheduled interval. To remove the oil filter use an oil filter wrench. To install a new oil filter, wipe the gasket-contact surface with engine oil, screw on the filter unit until gasket contacts the engine, and then tighten at least half a turn more. Do not use tools. Turn by hand only.

B-20. Positive Crankcase Ventilating Valve

For information on servicing the positive crankcase ventilating valve, refer to paragraph C-7.

B-21. Transmission and Transfer Case

Check paragraphs 22 through 24 where applicable.

B-22. Checking Lubricant Level

The transfer case and transmission must be serviced separately. The procedure in paragraphs B-23 and B-24 should be followed to check the lubricant level of the transfer case and transmission. If the transfer case or transmission fluid levels are found to be abnormally low, check for any possible leaks.

B-23. Transfer Case and Linkage

The transfer case fill-hole is located on the right side of the transfer case housing. To check the lubricant level, remove the fill plug. Lubricant should be level with this fill-hole. If not, bring up to level by adding sufficient lubricant as specified in the Lubrication Specifications. To change the lubricant, remove the transfer case fill-hole plug and then the transfer case drainhole plug. Let all fluid drain from case. Then install the transfer case drainhole plug, and refill the transfer case through the fillhole using the correct lubricant as specified in LO 9-2320-244-12. After filling transfer case to the correct level, install the filler plug and tighten securely. The transfer case shift linkage should be lubricated periodically. All bearing surfaces that are assembled with studs and cotter pins should be disassembled, cleaned, and coated with a good waterproof grease.

The bearing surfaces that cannot be disassembled should be lubricated with a lubricant that will penetrate the bearing area. These bearings include the two on the cross shaft assembly and the threaded stud.

B-24. Transmission

Check the lubricant level every 1,000 miles by removing the fill plug located on the right side of the transmission housing. Lubricant should be level with fill hole. Add lubricant as required and replace fill plug. Drain and refill every 12,000 miles. To change the lubricant, drain the old fluid by first removing the fillhole plug and then removing the drain hole plug.

When all the fluid is completely drained, replace the drainhole plug only. For the correct specifications and quantity, refer to LO 9-2320-244-12. After filling transmission to correct level, install filler plug and tighten securely.

B-25. Differentials

Check the lubricant level in the differential housing every 1,000 miles. Lubricant should be level with the filler plug openings. Add lubricant as required and replace filler plug. Drain and fill each 12,000 miles.

To remove the lubricant from the front or rear differential, it is necessary to remove the drain plug and filler plug. Let the lubricant drain out, and then flush the differential with a flushing oil or light engine oil to clean out the housing. Do not use water, steam, kerosene, or gasoline for flushing. Refill the differential housing as specified in LO 9-2320-244-12.

B-26. Steering Gear

Every 1,000 miles check that the steering gear lubricant is at the level of the fill-hole. If required, add lubricant to the level of the fill-hole with the lubricant recommended in LO 9-2320-244-12. If abnormally low, check the steering gear for possibility of leaks.

B-27. Lights and Controls

a. Check all interior and exterior lights and light switches for proper operation, including; parking lights, headlamps (high beam and low beam), tail lights, brake lights, directional lights, dome light, and instrument panel lights.

b. Check all instrument panel controls and instruments for proper operation.

B-28. Front Axle Universal Joint

Check the level of the front axle universal joint lubricant by removing the fill-hole plug. The lubricant should be level with the fill-hole. If required, add lubricant as specified in Lubrication Specifications.

Note: The forward inboard lower king pin bearing cap bolt should be used to drain any water contaminant from knuckle housings after fording operation

B-29. Clutch Cross Shaft

Lubricate the clutch cross shaft in accordance with specifications given in LO 9-2320-244-12.

B-30. Cooling System

Check the coolant level in the radiator. It should be half an inch below the neck. If reauired, fill the radiator to half-inch below the neck with the proper coolant. Refer to section 05.

If the level of the coolant is abnormally low, check the radiator, hoses and waterpump for possible leaks. If a leak is suspected, refer to section 05.

B-31. Door Latch Striker Plates

Clean all contact surfaces of the door latch striker plates. Apply a thin coat of Lubriplate to these surfaces. After lubrication, close the door several times to insure complete distribution of the lubricant. Wipe off excess lubricant from the striker plate.

B-32. Brake Master Cylinder

Clean the top of the fill cap and also the housing area around it. Remove the cap and observe the fluid level. It should be half an inch below the top of the fill-hole. If required, add brake fluid to one-half-inch below the top of the fill-hole, using only heavy-duty brake fluid conforming to specification VV-B-680. Be sure to handle the brake fluid in clean dispensers and containers that will not introduce even the slightest amount of other liquids or foreign particles. Replace and tighten the fill cap.

B-33. Air Cleaner

Standard air cleaner is a dry type as shown in figure B-2. For service refer to paragraph B-34.

B-34. Dry-Type Air Cleaner

Within the air cleaner housing is a replaceable element. Remove the element by unsnapping the retaining clips scuring the top of the air cleaner and then removing the top cover. Refer to figure B-2. Shake dust from the cartridge by tapping it against a flat surface, being careful not to deform the plastic seal. Compressed air may also be used to clean the element, if so—exercise caution to avoid damaging the filter material. Direct the air from inside the element toward the outside. Replace air cleaner cartridge at 12,000 miles, or sooner if plugged and causing loss of engine power.

Caution: Do not oil the element.

B-35. Tune Engine

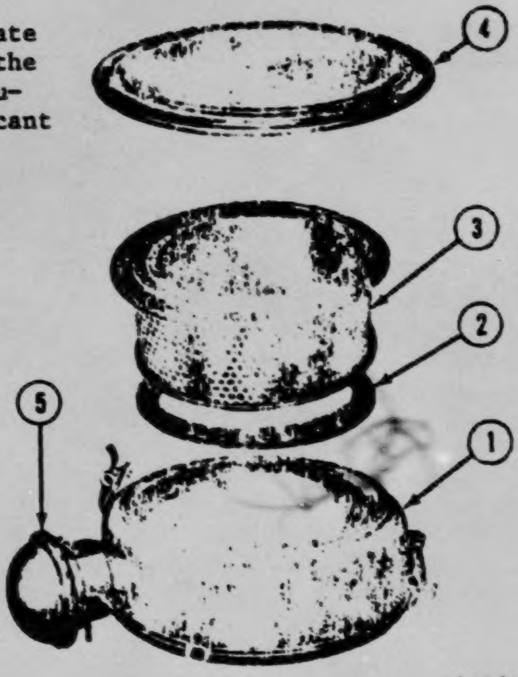
Refer to section C.

B-36. Rotate Tires

Refer to section 13.

B-37. Adjust Clutch

Refer to section 02.



1 Air cleaner housing
2 Gasket
3 Cartridge
4 Top cover
5 Drain reflector and precleaner

Figure B-2. Dry type air cleaner.

B-38. Adjust Brakes

Refer to section 12.

B-39. Adjust Fan Belt

Refer to section C.

B-40. Clean Exterior Radiator

For proper cooling efficiency the radiator should be cleaned of foreign objects. Refer to section 05.

B-41. Clean Body and Door Drain Holes

The M725 body has three door drain holes on the bottom of the door just outboard of the rubber seal and three body drain holes on each rocker panel. Also, one in each front and rear corner of the cab floor.

The M725 body has three door drain holes on each door and four body drain holes located on the lower inside lip of [illegible] rocker panel. Two other body drain holes are located about one door width rearward of each rear wheel well.

B-42. Door and Window Weatherstrips

Sparingly wipe silicon lubricant on all door weatherstrips and window weatherstrips. Wipe off any excess lubricant.

B-43 Door Latch Rotors

Clean and then apply a slight amount of Lubriplate to the door latch rotors. Wipe off any excess lubricant. Operate the latches several times. Again wipe off excess lubricant.

B-44. Tailgate Latch, Support and Hinges

Lubricate the friction points of the tailgate hinges with a few drops of lightweight engine oil.

B-45. Door and Hood Hinge Pivot Points

Lubricate the frictional points of the door and hood hinge pivot points with a few drops of lightweight engine oil.

B-46. Glove Compartment Door Latch and Hinges

Sparingly wipe Lubriplate on the glove compartment door latch. Lubricate hinges with a few drops of lightweight engine oil.

B-47. Heater Controls

Apply Lubriplate to all friction points and pivot points on the heater controls. Apply a few drops of penetrating oil all along the Bowden cable. This oil will penetrate into the center wire.

B-48. Windshield Wiper

Lubricate friction points and pivot points on the windshield wiper linkage with a slight amount of Lubriplate.

B-49. Headlights

Refer to section 06.

B-50. Brake Linings

Refer to section 12.

B-51. Exhaust System

Check the exhaust system for leaks. Refer to section 04.

B-52. Front End Rear Axle U-Bolts

Torque the front and rear axle U-bolts. Refer to sections 10 and 11.

B-52. Shock Absorbers

Visually check for broken mounts or bolts, worn or missing bushings on the shock absorbers. Refer to section 16.

B-54. Front and Rear Springs Bushings

The condition of the spring bushings is indicated by the alignment of the spring pivot and spring shackle bolts. Check the alignment of these bolts, make sure that nuts are tightened securely.

B-55. Spark Plugs

Replacement: Refer to section C.

B-56. Starting Circuit

Check the starting circuit. Refer to section 06.

B-57. Charging Circuit

Check the charging circuit. Refer to section 06.

B-58. Tie Rod and Drag Link Sockets

The tie rod and drag link sockets are equipped with lubrication fittings and should be lubricated at the interval specified in the Lubrication Chart.

B-59. Propeller Shaft Universal Joints and Slip Joints

The propeller shaft universal joints and slip joints are equipped with lubrication fittings. Proper lubrication of the U-joints, trunnion bearings and slip joint splines require special lubricants and not regular chassis lubricant.

Note: It is important that the universal joints be properly and fully lubricated. Whenever lubricating U-joints, add lubricant until it is visible coming out of each one of the four bearing seals.

B-60. Front Axle Universal Joint

The front axle universal joint should be serviced by removing the shaft and thoroughly cleaning the universal joints and housing with the correct procedures, refer to paragraph 10-5.

B-61. Front Axle Wheel Bearings

To lubricate the front wheel bearings, it is necessary to remove, clean, repack, and adjust them. When wheel hubs and bearing are removed for lubrication, they should be thoroughly washed in a suitable cleaning solvent. The bearings should be carefully dried and then given a thorough cleaning and inspection. Use a clean brush to remove all particles of old lubricant from bearings and hubs. After the bearings are cleaned, inspect them for pitted races and rollers. Also, check the hub oil seals. Repack the bearing cones and rollers with grease and reassemble hub in the reverse order of the disassembly. Test the bearing adjustment as outlined in section 13.

B-62. Rear Axle Wheel Bearings

To lubricate the rear wheel bearings are removed for lubrication, they should be thoroughly washed in a suitable cleaning solvent. The bearings should be carefully dried and then given a thorough cleaning and inspection. Use a clean brush to remove all particles of old lubricant from bearings and hubs. After the bearings are cleaned, inspect them for pitted races and rollers. Also, check the hub oil seals. Repack the bearing cones and rollers with grease and reassemble hub in the reverse order of the disassembly. Test the bearing adjustment as outlined in section 13.

B-63. Ignitor

Every 6,000 miles, remove the cap and rotor and apply 5 drops of medium engine oil to the felt in the top of the cam. Apply one drop of light oil to the breaker arm pivot pin. Operate arm once or twice, then remove excess oil. Apply a light film of grease to the breaker cam.

Note. Whenever ignitor cover is removed, a new O-ring should be installed and a waterproof test conducted.

At overhaul, soak drive shaft bearing in medium engine oil and drain before reassembling the distributor. Wipe all oil from upper part of base. At assembly apply a film of grease to the upper drive shaft washer and put a small amount of grease in the bearing bore just above the bearing. Lubricate the governor mechanism sparingly with medium engine oil. Put enough light grease in the felt wick reservoir so that when the wick is inserted the reservoir will be full.

B-64. Pintle Hook

The pintle hook and safety latch pivot pins are equipped with lubrication fittings and should be lubricated at the interval specified in the lubrication chart.

B-65. Winch

Lubricate and service in accordance with the specifications given in paragraph B-8 and LO 9-2320-244-12.

B-66. Parts Requiring No Lubrication

Refer to paragraphs 67 through 72.

B-67. Water Pump Bearing, Clutch Release Bearing

These bearings are prelubricated for life when manufactured and cannot be relubricated.

B-68. Starter Motor Bearings

These bearings are lubricated at assembly to last between normal rebuild periods.

B-69. Alternator Bearings

These bearings are lubricated at assembly and require no further lubrication.

B-70. Springs

The vehicle springs should not be lubricated. At assembly the leaves are coated with a long-lasting special lubricant designed to last the life of the springs. Spraying with the usual mixture of oil and kerosene has a tendency to wash this lubricant from between the leaves, making it necessary to relubricate often to eliminate squeaking.

B-71. Shock Absorbers

Hydraulic direct-action shock absorbers are permanently sealed and require no periodic lubrication service. Shock absorber mounting bushings are not to be lubricated.

B-72. Spring Shackles

Front springs are equipped with rubber bushings on the spring shackles and pivot bolts. These rubber bushings have no lubrication fitting and it is very important that they never be lubricated. Rear spring pivot fittings must be lubricated with a pressure gun.

B-73. Special Lubrication Requirements

Refer to paragraphs B-74 through B-76.

B-74. Lubrication Under Unusual Conditions

a. Reduce service intervals specified on the lubrication order and lubricate more frequently, to compensate for abnormal or extreme conditions, such as high or low temperatures, prolonged periods of high-speed operation, continued operation in sand or dust, immersion in water, or exposure to moisture. Any one of these operations or conditions may cause contamination and quickly destroy the protective qualities of the lubricants. Intervals may be extended during inactive periods commensurate with adequate preservation.

b. Lubricants are prescribed in accordance with three temperature ranges; above +32° F., +40° to −10° F., and from 0° to −65° F. (refer to LO 9-2320-244-12). Change the grade of lubricants whenever weather forecast data indicate that air temperatures will be consistently in the next higher or lower temperature range or when sluggish starting caused by lubricant thickening occurs. No change in grade will be made when a temporary rise in temperature is encountered.

c. Lubricant levels must be observed closely and necessary steps taken to replenish in order to maintain proper levels at all times.

B-75. Lubrication After Fording Operations

a. After any fording operation, in water 12 inches or over, lubricate all chassis points to cleanse bearings of water or grit as well as any other points required in accordance with maintenance operations after fording.

If the vehicle has been in deep water for a considerable length of time or was submerged beyond its fording capabilities, precautions must be taken as soon as practicable to avoid damage to the engine and other vehicle components.

b. Perform a complete lubrication service.

c. Inspect engine crankcase oil. If water or sludge is found, drain the oil and flush the engine with preservative engine oil. Before putting in new oil, replace the oil cartridge (para B-19).

Note. If preservative engine oil is not available, engine lubricating oil may be used.

d. Check the lubricant in the transmission, transfer case, and axles. Should there be evidence that water has entered, drain, flush, and refill with the correct lubricant. For assemblies which have to be disassembled, dried, and relubricated, perform these operations as soon as the situation permits. Wheel bearings must be disassembled and repacked after each submersion. Regardless of the temporary measures taken, the vehicle must be delivered as soon as practicable to the ordnance maintenance unit.

B-76. Lubrication After Operation Under Dusty or Sandy Conditions

After operation under dusty or sandy conditions, clean and inspect all points of lubrication for fouled lubricants and relubricate as necessary.

Note. A lubricant which is fouled by dust and sand makes an abrasive mixture that causes rapid wear or parts.

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LO9-2320-244-12

LUBRICATION CHART

CM "A" IS 3.1.1.1

TRUCK, CARGO, 1¼ TON, 4×4, M715

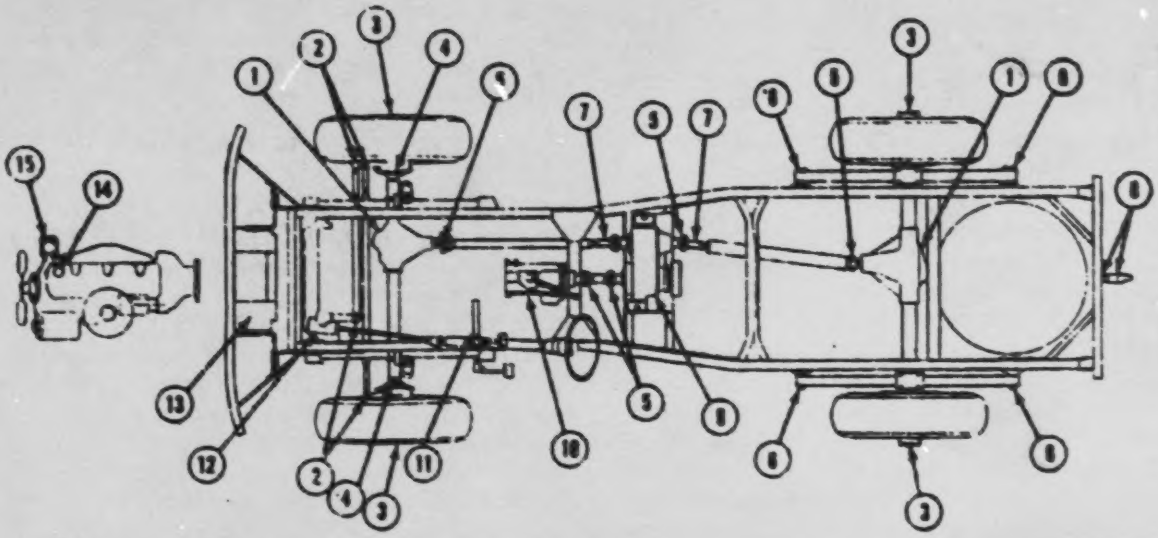

CHART NO.	ITEM TO BE LUBRICATED	MAINTENANCE OPERATION INTERVAL	QUANTITY	LUBRICANT Type	Grade Summer	Grade Winter
1	Differentials:					
	Front....	Weekly Check 12,000 Miles - Drain & Fill	6 pts	MIL L-2105	SAE 90	SAE 80
	Rear..	Weekly — Check 12,000 Miles Drain & Fill	6½ pts	MIL L-2105	SAE 90	SAE 80
2.	Steering Linkage (Tie Rod and Drag Link Sockets)	1000 Miles	As Required	MIL -		-
3.	Wheel Bearings:					
	Front........	12,000 Miles — Repack	As Required	MIL		—
	Rear..	12,000 Miles — Repack	As Required	MIL -	—	—
4.	Front Axle Universal Joint	1000 Miles — Refill 12,000 Miles — Change	1½ pts/joint	MIL	—	—
5.	Propeller Shaft Universal Joints	1000 Miles	As Required	MIL	.	—
6.	Spring Shackles and Pivots — Rear.	1000 Miles	As Required	MIL	--	-
7.	Propeller Shaft Slip Joints.	1000 Miles	As Required	MIL	--	—
8.	Pedals...	1000 Miles	As Required	MIL	-	
9.	Transfer Case........	Weekly — Check 12,000 Miles — Drain & Fill	3 pts	MIL-L-2105	SAE 90	SAE 80
10.	Transmission....	Weekly — Check 12,000 Miles — Drain & Fill	6½ pts	MIL-L-2105	SAE 90	SAE 80
11.	Clutch Release Cross Shaft	1000 Miles	As Required	MIL-	--	--
12.	Steering Gear.	Monthly — Check 12,000 Miles — Drain & Fill	1 pt	MIL-L-2105	SAE 90	SAE 80
13.	Winch Worm Case.....	Weekly — Check Drain & Refill Annually	2 pts	MIL-L-2105	SAE 90	SAE 90
14.	Engine....	6000 Miles — Drain & Refill	*5 qts	Engine Oil	**	**
15	Igniter - DISTRIBUTOR	6000 Miles	As Required	Lithium Grease	Soft	Soft

* When oil filter is changed at the same time add one quart.

** Above 32°F OE 30 HDO-30 ; 40°F to -10°F OE-10W HDO-10

MIL-L-2105 - HYPOID GEAR

LUBRICANTS	EXPECTED TEMPERATURES above +32°F	 +40°F to -10°F	 0°F to -60°F
OE - OIL LUBR, ENGINE	HDO 30 OE 30	HDO 10 OE 10	OES
MIL-L-2105 GO - LUBRICANT, GEAR, UNIVERSAL	GO 90	GO 75	GOS
HD-2 GREASE	HD2	HD 2	HD 2
HB - FLUID, HYDRAULIC, BRAKE	HB	HB	HBA

LUBRICANTS	INTERVALS See NOTE 10
OES - OIL, LUBR, ENGINE, SUB-ZERO	D - Daily (Operator)
GOS - LUBRICANT, GEAR UNIVERSAL, SUB-ZERO	1 - 1,000 Miles 6 - 6,000 Miles or semiannually *
HBA - FLUID, HYDRAULIC, BRAKE, ARCTIC	12 - 12,000 Miles or annually *
CW - LUBR, CHAIN, EXPOSED GEAR AND WIRE ROPE	*Whichever Occurs first

1. AIR CLEANER (Dry Type)
Every 1,000 miles (under normal conditions) remove air cleaner cover and inspect air cleaner cartridge (element). Clean if contaminated by shaking out (tapping) accumulated dirt or by washing with water and detergent only. Rinse until water runs clear. Shake off excess water and dry. Replace cartridge after five cleanings. Do not oil cartridge. For desert or extremely dusty operation clean as often as required.

2. CRANKCASE
Drain every 6,000 miles or semiannually. Drain only when hot after operation. Before filling crankcase remove filter screen in oil filler neck and clean. Check gasket in oil filler cap, replace if required. Reinstall screen and refill to FULL mark on gage. Run engine a few minutes and recheck oil level.

3. OIL FILTER
Replace oil filter after first 500 miles. Every 6,000 miles or semiannually, while draining crankcase, remove oil filter assembly and discard. Install new oil filter assembly. Hand tighten only.

4. DISTRIBUTOR
Every 6,000 miles or semiannually remove distributor. Remove plug under nameplate and withdraw felt wick. Soak wick in OE. Fill plug opening with HD2 insert wick, remove excess grease and install plug. Wipe breaker cam lightly with HD2 and breaker arm pivot with 1 to 2 drops of OE. Install distributor.

5. GEAR CASES
Drain every 12,000 miles or annually. Drain only when hot after operation. Fill to plug levels before operation and after draining. (W/O PTO - without power take-off; W/PTO- with power take-off).

6. FRONT WHEEL UNIVERSAL JOINTS AND STEERING KNUCKLE BEARINGS
Every 1,000 miles remove plug and lubricate through plug located at side of steering knuckle housing until lubricant appears at plughole. Install plug. If required, disassemble constant velocity universal joints every 12,000 miles or annually. (Remove lower screw on housing after fording.)

7. WINCH CABLE
After each operation, clean and oil with engine oil (OE). Every 6,000 miles or semiannually if cable is not generally used, unwind entire cable, clean and soak by means of a brush with OE. Wipe off excess and coat cable with CW. Coat winch drum also with CW before rewinding cable on drum.

8. FUEL FILTER
Every 12,000 miles or annually replace in-line fuel filter. Also remove screen in fuel tank filler neck and clean.

9. CRANKCASE VENTILATION VALVE
Every 6,000 miles or semiannually remove crankcase ventilation valve and wire mesh which are housed in rubber hose leading from crankcase-to-air cleaner. Clean hose and fittings as required. Install mesh and valve in hose and install to engine. Check oil filler cap gasket (See Note 2).

10. LUBRICATION INTERVALS
When practicable, Lubrication Service will be made to coincide with the vehicle "S" P.M. Service. For this purpose a 10% tolerance (variation) in specified lubrication point mileage is permissible.
NOTE: After vehicles have reached 6,000 miles or 2 years, whichever occurs first, lubrication intervals will be performed at 3,000 miles.

11. OIL CAN POINTS
Every 1,000 miles lubricate clutch and brake pedal shafts and linkage, accelerator pedal shaft and pivots, throttle bellcrank, parking brake linkage, winch shifter shaft, seat hinges and adjuster, all compartment hinges, catches, and locks, door handles, tail gate hinges and catches, lifting eye pins (4), spare tire carrier bolt.

12. BRAKE FLUID
Use hydraulic brake fluid (HB) non-petroleum base only. Use of hydraulic brake fluid petroleum base renders brakes inoperative.

13. DO NOT LUBRICATE
Shock absorbers and mounting bushings, front spring shackles, spring leaves, generator, and starter. Water pump and clutch release bearings are prelubricated at manufacture and cannot be relubricated.

NAVAL CONSTRUCTION TRAINING CENTER
PORT HUENEME, CALIFORNIA 93043

CONSTRUCTION MECHANIC "A" J.S. 3.1.1.1

COURSE A-610-0022

TITLE: Servicing the power train of the M-715 1-1/4 ton cargo truck M-725 field ambulance and M-726 telephone maintenance truck 4 X 4 hereafter referred to as the M-715.

INTRODUCTION: The purpose of this job sheet is to guide you in the practical performance of removing, disassembling, inspecting, repairing, and adjusting the power train components of the M-715. They will cover orderly removal of transmission assembly, clutch, differential; steering, brakes, and tires.

You will select and safely use all tools and equipment required to accomplish all procedures on this job sheet.

All safety precautions that are applicable to you, your team mate, and the equipment must be observed at all times.

Every procedure must be done in accordance with this job sheet and the manufacturer's specifications without error.

TOOLS AND EQUIPMENT PROVIDED:

1.	Air compressor	2HC 4310-00-901-0727
2.	Automotive mechanics tool kit	
3.	Bench grinder	9GD 3415-00-517-7754
4.	Hydraulic brake bleeder tank	9HD 4910-00-273-3658
5.	Dial indicator	
6.	Oil drain pan	
7.	Grease gun	9CD 4930-00-253-2478
8.	Hypoid gear oil can	
9.	Tire demounter	
10.	Tire patching kits	
11.	Tool kit, M-715 (Series) differential	
12.	Transmission floor jack	1HC 4910-00-554-3542

TOOLS AND EQUIPMENT PROVIDED (Cont.)

13.	Truck M-71- (Series) 1-1/4 ton cargo	
14.	Manufacturer's Service Manual	
15.	Task job sheet	
16.	Jack stand	1HC 4910-00-869-8058
17.	Fly wheel turner	
18.	Wooden blocks	
19.	Cloth rags	
20.	Foot LB 1/2" drive torque wrench	9QG-5120-00-640-6365
21.	Tire safety cage	1HV-4910-00-204-2448
22.	900 X 16 8-ply NDMS tire w/rim	
23.	Automotive rim w/tire	

I. CONDITIONS:

A. Student teams (2-3 men each) are assigned to an M-715 1-1/4 ton cargo truck to accomplish the task of removal, disassembly, inspection of parts for wear, replacement, reassembly, and adjustment of power train components.

II. PROCEDURES: As outlined on the attached pages of the EWO and continuation sheets.

A. Steering gear

B. Tire service

C. Transmission

D. Clutch

E. Differential

F. Brakes

G. Chassis lubrication

H. Air cleaner/crankcase ventilation

EQUIPMENT WORK ORDER
NAVFAC 6-11200/41 (REV 5-69)
S/N 0105-002-5886

THIS "EWO" IS TO BE USED FOR REPAIR OF ALL EQUIPMENT ASSIGNED:
NAVAL CONSTRUCTION FORCES
SPECIAL OPERATIONAL UNITS
NAVAL CONSTRUCTION SCHOOLS

1. USN NO 266 9 4 6 9 9 6 3

2. E A C NO CM "A" JS 3.1.1.1

3. Page 4 of 7

4. Automotive Chassis

5. UNIT ID CODE

6. ZIP CODE

7. EQUIP. CODE 0 3 6 0

8. UNIT IDENTIFICATION NAVCONSTRACEN

9. MAKE KAISER

10. MODEL M-715

11. YR OF MFG 6 8

12. MILES

13. HOURS

14. EQUIPMENT DESCRIPTION Truck,Cargo 1¼ Ton 4 x 4

Use all available space for reporting man-hours ... inspection time, when estimates are prepared for a customer prior to authorization to proceed with repairs.

15. DATE IN

OUT

16. INSPECTION MAN-HOURS INSPECTOR

MECHANIC

17. TOTAL HOURS Add to Block (37)

18. TYPE MAINTENANCE REPAIR Check appropriate box

PM SERVICE DUE A(1)	B(2)	C(3)	INTERIM (4)	OVERHAUL (5)
		XXX		

19. LAST PM SERVICES (Miles or Hours) Indicate "M" for Miles; "H" for Hours.

"A"	"B"	"C"

MATERIAL RECORD

20. FSN MFG PART	21. DESCRIPTION	22. QTY.	23. COST	24. WORK CTR.	25. LCC	26. MAN-HOURS EST.	26. MAN-HOURS ACT.	27. WORK DESCRIPTION	27A. P OR S	28. MECH. INIT.
				A				Remove Steering Gear Case. Dis-Assemble & Inspect For Worn Or Defective Parts. Renew As Req-Uired. Reassemble And Adjust To Manufacturer's Specification's Reinstall		
				B				Tire Service As Performed On Page &		
				C				Remove Transmission,Disassemble & Inspect For Worn Or Defective Parts. Replace As Required		
				D				Remove Clutch Pressure Plate, Disc & Throw-Out Bearing.		

Enter portion of Col. 23 that is OPERATING COST → 29. $

30. $ ← Enter portion of Col. 23 that is MAINTENANCE COST

	TIME	DATE	32. JULIAN DATE
COMPLETED	31A		
PARTS AVAILABLE			DFM
STOP FOR PARTS			DFM
PARTS AVAILABLE			DFM
STOP FOR PARTS			DFS
INSPECTION STAFF	31B		DFM
EQUIPMENT AVAILABLE	31C	31D JULIAN DATE	32A JULIAN DATE

33. TOTAL DOWN FOR MAINT. TIME

34. TOTAL DOWN FOR SUPPLY TIME

35. FUNCTION GROUP (Check appropriate blocks) → 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24

36. SIGNATURES

		DATE
INSPECTOR	CM 1 Kemper	07 Dec
MAINTENANCE SUPERVISOR	CMC Mayhew	07 Dec
SECTION SUPERVISOR	CMC Baker	08 Dec

INITIAL

37. WHOLE HOURS ← TOTAL ACTUAL LABOR HOURS

OPERATING COST 38. DOLLARS CENTS

MAINTENANCE COST 39. DOLLARS CENTS

40. TOTAL COST $

B. Tire Service:

NOTE: The procedural steps for disassembly and reassembly of the split-rim vehicle tire will be performed by one team under direct supervision of an instructor.

1. Demounting tubeless or tube-type tires:

   a. Place wheel on the conical contour table of the tire demounter machine.

   b. Deflate tire by removing the valve core.

   c. Position the tire with the valve midway between the bead-loosener shoes.

   d. Remove all weights from top rim flange.

   e. Position hold-down cone properly.

   f. Set detent control knob to proper rim size, position top bead loosening guide.

   g. Place combination tool under tire bead and the other end over center post key.

   h. Press foot pedal valve.

2. Mounting tubeless or tube-type tires.

   NOTE: Use extreme caution when seating or inflating tires - never place your head over the tire - pneumatic pressure can kill or maim.

   a. Apply rubber lubrication to the bead before mounting tire on the rim.

   b. Place tire over the wheel rim at an angle.

   c. Place or hook the mounting end of the combination tool over the rim flange, and insert the other end over the center post key.

   d. Depress foot pedal valve.

   e. Repeat step (2b) for the top bead mounting.

   f. Loosen "but do not remove" hold-down cone.

g. Place bead expander over outside of tire and inflate "Do not exceed 5 P.S.I."

h. Inflate until bead sets.

i. Remove bead expander.

j. Remove hold-down cone.

k. Install valve core and inflate tire to specified tire pressure.

l. Remove tire assembly from tire demounting machine.

Instructor Check Point ____________________

3. Repair of inner tubes (cold patch):

   a. Roughen the injured area to exceed the patch size.

   b. Apply rubber cement to roughened area, allow the cement to air-dry for a few seconds.

   c. Position the patch squarely over the injured area. "Keep fingers off the clean area of the patch".

   d. Use knurled wheel from patch kit, and roll patch from center to edge. Repeat this process a few times to insure the patch is seated.

   e. Inflate tube and check for air leak.

Instructor Check Point ____________________

4. Repair of inner tubes (hot patch):

   a. Roughen the injured area to exceed the patch size.

   b. Select right sized hot patch for the injured area.

   c. Remove the protective cover from bottom of patch, and place patch squarely over the injured area.

   d. Position inner tube and hot patch in the clamp vise and tighten.

   e. Ignite the hot patch burnable material.

   f. Allow the metal portion to cool (2-3 min.) loosen the clamp vise, remove the inner tube, discard the metal portion.

   g. Inflate tube and check for air leak.

Instructor Check Point ____________________

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CONSTRUCTION MECHANIC SCHOOL
NAVAL CONSTRUCTION TRAINING CENTER
PORT HUENEME, CALIFORNIA 93043

CLASS "A"

TOPIC 3.1.1. SUSPENSION FIELD TEST #1

1. The most common type of frame design in use on 6 x 6 trucks 2½ ton and 5 ton:

   a. Box design or channel.
   b. X member design.
   c. Unit body design.
   d. I beam design.

2. The most common type of shock absorber in use for automotive vehicles is the:

   a. Single-acting type.
   b. Double-acting, parallel piston type.
   c. Double-acting, telescoping type.
   d. Double-acting opposed-piston type.

3. Which of the following statement is NOT correct?

   a. Springs are bolted or pin-connected to the spring shackles and hangers.
   b. Spring shackles connect the spring assembly rigidly to the axle assembly.
   c. Spring clips (U bolts) connect the spring assembly rigidly to the axle assembly.
   d. Spring rebound clips stop spring leafs from separating on compression and rebound.

4. When removing springs from a vehicle, the first step to take is to:

   a. Remove the shackle pins.
   b. Remove the spring clips.
   c. Place safety stands under the frame.
   d. Remove the rebound clips.

5. The basic types of wheel suspension systems are.

   a. Beam type, independent, and kingpin.
   b. Beam type, independent and bogie.
   c. Beam type, independent, twin I-beam.
   d. Beam type, kingpin and ball joint.

6. The most common type tire rim found on passenger cars and small trucks is.

a. Safety rim.
b. Split rim.
c. Both a & d
d. Drop center.

7. The types of steering gear units are re-circulating ball, worm and roller, worm and sector and:

a. Lever and roller.
b. Cam and worm.
c. Roller and sector.
d. Cam and lever.

8. Tires with the "V" type directional tread should be mounted on the drive axle.

a. With the point of the "V" so that it meets the ground last.
b. It makes no difference.
c. With the point of the "V" so that it meets the ground first.
d. None of the above.

9. What two adjustments can be made on the worm and roller steering gear assembly?

a. Backlash and cross shaft bearing preload.
b. Bearing preload and backlash.
c. Cross shaft backlash and cam bearing preload.
d. Cam bearing backlash and cross shaft preload.

10. The purpose of wheel balance is:

a. For easier steering.
b. To prevent rough riding.
c. To prevent tire wear.
d. For all of the above.

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CONSTRUCTION MECHANIC SCHOOL
NAVAL CONSTRUCTION TRAINING CENTER
PORT HUENEME, CA. 93043

CLASS "A"

TOPIC 3.1.2. POWER TRAIN FIELD TEST #2

1. What is the usual result in clutch operation when there is excessive clutch pedal travel.

   a. There is no effect on clutch operation.
   b. The clutch will slip while engaged.
   c. The clutch will not disengage.
   d. There is excessive wear on the release bearing.

2. How many drive surfaces are employed in a single-disk type automotive clutch?

   a. One
   b. Two
   c. Three
   d. Four

3. The purpose of the clutch pilot bearing is to:

   a. Align the pressure plate.
   b. Support one end of the transmission main shaft.
   c. Support one end of the clutch shaft.
   d. Support one end of the crankshaft.

4. Which of the following parts of the clutch will not be rotating when the engine is running, clutch disengaged?

   a. Pressure plate.
   b. Release bearing.
   c. Clutch drive disk and clutch shaft.
   d. Clutch cover and spring assembly.

5. In many new trucks with "straight stick" transmissions, double clutching is eliminated.

   a. By using sliding gears of the spur type.
   b. By using sliding gears of the spiral type.
   c. By using a synchromesh device.
   d. By using a combination of constant mesh and sliding gears.

6. The most common type differential in use on modern autos is the:

   a. Spur-bevel type.
   b. Worm and spur type.
   c. Spiral-bevel type.
   d. Hypoid type.

7. The first adjustment to be made when repairing a differential gear assembly is to:

    a. Adjust the run-out.
    b. Adjust the pinion preload.
    c. Adjust the tooth contact.
    d. Pre-load the carrier bearings.

8. Most military trucks use a transfer case to deliver power to:

    a. The front wheels only.
    b. The rear wheels only.
    c. The four rear driving wheels only.
    d. All driving wheels, front and rear.

9. One purpose of the automotive power take off unit is to:

    a. Act as an emergency transmission.
    b. Furnish a dual speed gear ratio.
    c. Change the direction of the power flow.
    d. Operate the winch.

10. The side gears and the differential pinion gears rotate in the differential carrier when the vehicle is:

    a. Proceeding straight down the highway.
    b. Turning right or left.
    c. Backing straight down the highway.
    d. Climbing a steep grade.

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CONSTRUCTION MECHANIC SCHOOL
NAVAL CONSTRUCTION TRAINING CENTER
PORT HUENEME, CALIFORNIA 93043

CLASS "A"

TOPIC 3.1.3. BRAKE SERVICE FIELD TEST #3

1. The purpose of the vent hole in the master cylinder filler cap is to:

   a. Allow the atmospheric pressure to keep the cylinder filled with fluid.
   b. Allow the excess fluid to escape from the reservoir.
   c. Allow excessive fluid to enter the reservoir.
   d. Allow excess atmospheric pressure to escape from the reservoir.

2. On of the functions of the return spring in the brake master cylinder is to.

   a. Hold the primary cup in an upright position.
   b. Hold the edges of the primary cup against the cylinder walls.
   c. Maintain 10 psi of pressure in the brake lines.
   d. Act as a valve to open and close the by-pass port.

3. A malfunctioning check valve in the brake master cylinder might cause

   a. Leakage at the wheel cylinders.
   b. Excess pressure build-up in the lines.
   c. Brake shoes to drag against the drums.
   d. A loss of pressure in the master cylinder.

4. When bleeding air from the hydraulic brake system, which of the following should be bled first?

   a. The suspected wheel cylinder.
   b. Both front wheel cylinders.
   c. The wheel farthest from the master cylinder.
   d. The wheel nearest the master cylinder.

5. The primary function of the brake "backing-plate" is to.

   a. Keep dust out of the wheels moving parts.
   b. Help support the wheel and drum.
   c. Support the brake shoes.
   d. Support the wheel cylinder and anchor pins.

6. Brake drums are usually made of cast iron because it.

   a. Makes the drums lighter.
   b. Makes the drums stronger.
   c. Makes the drums operate cooler.
   d. Makes the drums heat evenly.

7. The slave cylinder and piston in the air over hydraulic brake is used to:

   a. Aid the master cylinder check valve in keeping 10 psi of pressure on the brake lines.
   b. Control the amount of atmospheric pressure and vacuum to the power unit.
   c. Step up hydraulic pressure and give more positive application of brakes.
   d. Replace the "old type" master cylinder unit and its lingage.

8. In the Bendix Air Pac, the control valve is operated by what means?

   a. Mechanically.
   b. Hydraulic pressure.
   c. Air pressure.
   d. Vacuum.

9. Most air brake systems have two receiver tanks so as to.

   a. Store compressed air for pulled trailer units as well as the trucks own brakes.
   b. Furnish a means of collecting condensation which may be formed due to compression heat.
   c. Have a constant volume of air pressure to operate the compressor unloader head.
   d. All of the above are true.

10. The "slack adjuster" on an air brake unit is the adjustment unit which compensates for.

   a. Incorrect pedal linkage.
   b. Incorrect governor control settings.
   c. Major adjustments of the brake shoes.
   d. Normal brake lining wear.

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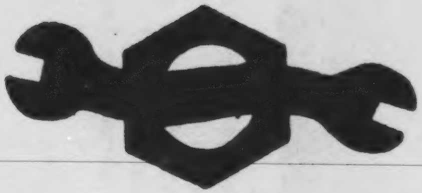
CONSTRUCTION MECHANIC SCHOOL

CLASS "A"

INSTRUCTOR GUIDES

PHASE 4



Crawler Tractor Power Train Maintenance

3. Materials (Consumable):
    - a. Welding gloves.
    - b. Welding goggles.
    - c. Face shields.
    - d. Sheet metal.
    - e. Oxygen.
    - f. Mapp gas.
    - g. Igniters.
    - h. Hoses.
    - i. Tips.
    - j. Tip cleaners.

D. Training Aids and Devices:

1. Films.
    - a. MV9861 "Oxyacetylene Cutting Manual", (9 min.).
    - b. MN-1921-G, "Safety for Welders", (7 min.).

2. Locally Prepared Materials:
    - a. Job Sheet.
        - (1) CM "A" JS 4.1.1.1, "Oxy-Mapp Gas Heating and Cutting".

E. Training Aids Equipment:

1. 16mm Sound movie projector.

Criterion Test: Light off and adjust flame of Oxy-Mapp gas outfit to safely perform heating and cutting operations as established by Job Sheet without deviation.

Homework: Study SW 3 & 2, NAVPERS 10653-E, pp. 152 - 170 and 187 - 220.

OUTLINE OF INSTRUCTION	INSTRUCTOR ACTIVITY	STUDENT ACTIVITY
I. Introduction to the lesson.		
A. Establish contact.	I.A. Introduce self and topic.	
1. Name:		
2. Topic: Oxy-Mapp Heating and Cutting		
B. Establish readiness.	I.B. Motivate student.	
1. Purpose.		
2. Assignment.		
C. Establish effect.	I.C. Bring out need and value of material being presented.	
1. Value.		
a. Pass course.		
b. Perform better on the job.		
c. Get advanced.		
d. Be a better mechanic.		
D. Overview:	I.D. State learning objectives.	
1. State objectives.	1. State information and materials necessary to guide student.	
2. Take notes.		
3. Ask questions.		
4. Materials.		

OUTLINE OF INSTRUCTION	INSTRUCTOR ACTIVITY	STUDENT ACTIVITY
II. Presentation.		
A. Welding Gases.		
1. Mapp Gas.		
a. Characteristics.		
(1) A chemical liquid compound of Methylacetylene Propadiene (Mapp Gas) is used as a replacement for Acetylene due to ease and safety in shipping.	II.A.1.a.(1) Show how Mapp and Acetylene cylinders differ and why.	II.A.1.a.(1) Inspect cylinders.
(2) Colorless and has a sewage odor which is detectable at very low levels.	II.A.1.a.(2) Crack valve and permit small amount of Mapp gas to escape.	II.A.1.a.(2) Smell gas to recognize odor.
b. Stowage: Stowed and used Upright. Each cylinder contains 70 lbs of liquid Mapp. If cylinders have been layed down, stand up for use.		
c. Safety: Cylinders yellow in color; contains no packing material. Safety valve releases at 375 PSI and resets at 350 PSI.	II.A.1.c. Point out location of safety valve.	II.A.1.c. Inspect safety valve.
B. Oxygen.		
1. Characteristics.	II.B.1. Display cylinder and release some gas.	II.B.1. Note that oxygen has no odor.
a. Colorless, odorless and tasteless.		
b. Will not burn, but supports combustion.		
c. Industrial is not for breathing.		

OUTLINE OF INSTRUCTION	INSTRUCTOR ACTIVITY	STUDENT ACTIVITY
2. Stowage.	II.B.2. Stress the importance of keeping oil and grease away from oxygen.	
a. Stowed upright and separated from Acetylene and Mapp gas by fireproof partition.		
3. Safety.	II.B.3. Point out position of safety plug.	II.B.3. Inspect safety plug.
a. Cylinders are green in color.		
b. Safety plug.		
(1) Located on back of cylinder valve.		
(2) Ruptures at 2600 to 3000 PSI.		
(3) Melts at 208° - 220°F.		
c. Cylinders contain no packing material.		
d. Cylinder contains 200 cu. ft. of gas at approximately 2000 PSI.		
NOTE: "Remember" put the steel cap back on both oxy and Mapp bottles unless regulators are attached.		
C. Welding equipment.		
1. Regulators.		
a. Single-stage regulator.		
(1) Reduces gas pressure in one step.		
(2) Most common used and simplest in construction.		

OUTLINE OF INSTRUCTION	INSTRUCTOR ACTIVITY	STUDENT ACTIVITY
b. Two-stage regulator.		
(1) Reduces gas pressure in two steps.		
(2) Most effective and efficient.		
2. Operation of regulator.		
a. Turn adjusting screw in (clockwise) to increase working pressure.		
b. Turning adjusting screw out (counter-clockwise) decreases working pressure.		
3. Gauges.		
a. Oxygen.		
(1) High pressure gauge show cylinder pressure.	II.C.3.a.(1) Point out which is the cylinder pressure gauge and which is the line pressure gauge.	II.C.3.a.(1) Inspect regulators.
(a) 3000 PSI (High reading safety factor).		
(b) Shows cu. ft. oxygen remaining in cylinder.		
(2) Low pressure oxygen (working pressure).	II.C.3.a.(2) Attach Mapp gas regulator to Mapp tank, and oxygen regulator to oxygen tank.	
(a) 50 PSI for welding and cutting.	II.C.3.a.(2)(a) Point out that the Mapp regulator has left-hand threads and the oxygen regulator has right-hand threads.	

OUTLINE OF INSTRUCTION	INSTRUCTOR ACTIVITY	STUDENT ACTIVITY
(b) 200 PSI for cutting.		
(c) 400 PSI for heavy cutting.		
b. Mapp.		
(1) High pressure gauge show cylinder pressure.		
(a) 500 PSI (high reading safety factor).		
(b) Shows cu. ft. Mapp remaining in cylinder.		
(2) Low pressure gauge shows working pressure.		
NOTE: Acetylene regulators are used for Mapp gas.		
4. Welding hose.		
a. Oxygen.		
(1) Green or black color.		
(2) Connections are right-hand threads.		
b. Mapp.	II.C.4.b. Point out the Mapp hose connections have a groove.	
(1) Red in color.		
(2) Connections are left-hand threads.	II.C.4.b.(2) Connect hoses to regulators.	

OUTLINE OF INSTRUCTION	INSTRUCTOR ACTIVITY	STUDENT ACTIVITY
5. Welding torches (butts).		
a. Two general classes.		
(1) Medium or equal pressure (most used).		
(a) Gases delivered above 1 PSI.		
(2) Injector or low pressure.		
(a) Mapp pressure under 1 PSI.		
(b) Oxygen pressure 10 to 50 PSI.		
NOTE: All are designed to supply equal parts of oxygen and Mapp at the torch tip.	Connect torch butt to hoses.	
6. Welding tips:		
a. Controls volume of heat.		
b. Size of tip measured by diameter of tips hole.		
c. Tips are countersunk for Mapp gas (gives a more stable flame).	II.C.6.c. Connect welding tip to torch butt.	II.C.6.c. Inspect completed hook-up.
7. Cutting torches and tips:	II.C.7. Remove torch tip and connect cutting attachment.	II.C.7. Inspect cutting attachment hook-up.
a. Cutting torch.		
(1) Hose connects directly to torch.		
b. Cutting attachments.		
(1) Connect directly to welding torch (butt).		

c. Cutting tips for Mapp and oxygen.

(1) One large hole in center for jet of oxygen.

(2) Eight or more slits around center for preheat.

NOTE: Never use Mapp gas modified tips with Acetylene because of backflash.

D. Theory of Oxy-Mapp cutting.

II.D. Introduce and show film, MV9861 "Oxyacetylene Cutting Manual" (9 min.). Review high points of film.

II.D. Take notes.

1. All matter oxidizes.

a. Ferrous metals rust.

b. Non-ferrous metals corrode.

c. Wood rots.

2. Oxygen is required to keep a fire burning.

3. The preheating flames heat the metals to their kindling temperature.

a. 1400 to 1600°F.

E. Metals that can be cut.

1. Wrought iron.

2. Cast steels.

3. Carbon steels.

4. Alloyed steels.

OUTLINE OF INSTRUCTION	INSTRUCTOR ACTIVITY	STUDENT ACTIVITY
F. Pre-cutting procedures. 1. Selection of cutting tip. a. Thickness of metal. b. Type of cut to be made. (1) Heavy cutting. (2) General cutting. (3) Rivet cutting.	II.F. 1. Discuss films and theory of gas cutting. 2. Hook up regulators, hoses torch butt and cutting replacement. 3. Light and adjust cutting flame. 4. Show the students the difference between the Mapp and Acetylene cutting tips. 5. Select correct size tip for metal thickness to be cut.	II.F. 1. Practice lighting and adjusting flame. 2. Attach correct size cutting tip to cutting adjustment.
2. Select correct oxygen and Mapp pressure for tip. a. Mapp - 3 - 10 PSI for plate up to 3" thick. b. Oxygen - 5 - 10 PSI for plate up to 1" thick, 10 - 20 PSI for plate 1" to 2" thick, and 10 - 30 PSI for plate 2 1/2" to 6" thick.	II.F.2. Adjust regulators for correct pressure for size of tip.	II.F.2. Adjust regulators for correct pressure.
3. To start cut: a. Adjust flame to neutral. b. Test to see that flame remains neutral, by releasing a stream of oxygen.	II.F.3.b. Light torch and adjust to neutral.	
G. Cutting procedures. 1. Neutral flame a must on all cuts. 2. Metal is heated to cherry red or kindling temperature on all cuts.		

OUTLINE OF INSTRUCTION	INSTRUCTOR ACTIVITY	STUDENT ACTIVITY
3. Always check your surroundings for combustible materials.		
4. Never cut on or in a tank or container until a safety check has been made.		
5. A straight cut.		
a. Hold heating flames approximately 1/16" above the metal.	II.G.5.a. Make a straight line cut.	II.G.5.a. Light torch.
b. Tilt torch to thin edge for rapid heat-up.		
c. Release oxygen when steel is to the kindling point.		
d. Hold torch steady along line of cut.		II.G.5.d. Make a straight line cut.
H. Faults in cutting.	II.H. Demonstrate results of faults in cutting.	
1. Preheat flame.		
a. Too short.		
(1) Cut looks gouged at bottom.		
b. Too long.		
(1) Top edge of cut melted.		
2. Oxygen pressure.		
a. Too low.		
(1) Top edge of cut melted.		

OUTLINE OF INSTRUCTION	INSTRUCTOR ACTIVITY	STUDENT ACTIVITY
b. Too high.		
(1) Cut rough and uneven.		
3. Cutting speed.		
a. Too slow.		
(1) Drag lines uneven.		
b. Too fast.		
(1) Drag lines rough.		
4. Bottom of kerf (the narrow slit that is formed) should be clean of slag or oxides, if not clean the tip.		
I. Safety in cutting.	II.I. Introduce and show film NM1021G "Safety for Welders". a. Review high points of film.	II.I. View film and take notes. a. Participate in discussion.
1. Tips.		
a. Never use Mapp gas cutting tips with Acetylene.		
b. Acetylene cutting equipment can be used safely with Mapp.		
III. Application.		
A. Practical exercises in lighting off and adjust flame of Oxy-Mapp gas outfit to safely perform heating and cutting operations as established by job sheet without deviation.	III.A. Direct, supervise and evaluate student heating and cutting exercise.	III.A. Light off and adjust flame of Oxy-Mapp gas outfit to safely perform heating and cutting operations as established by job sheet without deviation.

OUTLINE OF INSTRUCTION **INSTRUCTOR ACTIVITY** **STUDENT ACTIVITY**

IV. Summary.

A. Welding gases.

B. Oxygen.

C. Welding equipment.

D. Theory of Oxy-Mapp cutting.

E. Metals that can be readily cut.

F. Pre-cutting procedures.

G. Cutting procedures.

H. Faults in cutting.

I. Safety in cutting.

V. Test:

A. End of unit test.

NAVAL CONSTRUCTION TRAINING CENTER
PORT HUENEME, CALIFORNIA 93043
CONSTRUCTION MECHANIC "A" SCHOOL TRAINING COURSE A-610-0022

Classification: Unclassified

Topic: Construction Equipment Power Trains

Average Time: 12 Periods (Class), 30 Periods (Pract)

Instructional Materials:

A. Texts:

1. Operation and Maintenance Instructions, Caterpillar D4D Tractor, Serial No's 78A1-UP, 86A1-UP, Form 34887-2, pages 61 - 81.

2. Service Manual for Caterpillar D4D Tractor, Serial No. 78A1-UP, Sec. 15B-30, Groups 2C, 40, 70, 80, 90, 110, 119, 120, 140, 160 and 180.

3. Service Manual, International Model 250 and 250 Series B Loaders and TD-20 Series B Crawler Tractor Chassis, Form ISS-1050-1, Section 6. International Harvestor Co., 401 North Michigan Avenue, Chicago, Illinois 60611.

4. Service Manual, Caterpillar D-8 Tractor, Serial number 35A1-UP, 36A1-36A4468; 46A1-46A1-0724 Group 65.1, Page 1, Caterpillar Tractor Co., Peoria, Illinois.

B. References: None.

C. Tools, Equipment and Materials:

Terminal Objective: Upon completion of this unit each student will be able to service the power train and chassis units of the Caterpillar D4D Crawler Tractor. Using appropriate handtools, special tools, shop equipment and Oxy-Mapp gas outfit, he will remove, disassemble, inspect, and replace worn parts, assemble and adjust the master clutch, transmission, steering clutches, final drive/sprocket assembly, bevelgear assembly and track-roller frame assembly. All tasks will meet manufacturer's specifications without deviation as specified in Job Sheets CM "A" JS 4.1.1.1, "Oxy-Mapp Gas Heating and Cutting", and CM "A" JS 4.1.2.1, "Servicing the D4D Caterpillar Crawler Tractor Power Train". Adjust the International Model 260 Cable Control Unit using appropriate handtools and shop equipment. All adjustments will conform without deviation to manufacturer's specifications as specified in the Job Sheet CM "A" JS 4.1.3.1, "Adjusting International Model 260 Cable Control Units".

Enabling Objectives: Upon completion of this topic each student will be able to service the power train and chassis units of the Caterpillar D4D Crawler Tractor while working as a member of a team using appropriate handtools, special tools, shop equipment and materials. Specifically, he will remove, disassemble, inspect, replace worn parts, assemble and adjust the master clutch, transmission, steering clutches, final drive/sprocket, bevelgear assembly, and track roller frame assembly.

1. Tools:

    a. Heavy equipment handtools.

    b. Caterpillar crawler tractor tools.

2. Equipment:

    a. Major.

        (1) Caterpillar D4D Crawler Tractor (6 each).

3. Materials: (Consumable).

    a. Cleaning solvent.

    b. Grease.

    c. Gear oil.

    d. Diesel fuel.

    e. Wiping rags.

D. Training Aids and Devices:

1. Films:

    a. MH-10017 "It Can Happen", International Harvestor Co. (Color, 20 min.).

    b. MN-8146 "The Gamblers", Caterpillar Tractor Co. (Color, 20 min.).

    c. ROL-002 "The Roll of Drums", Caterpillar Tractor Co. (Color, 20 min.).

All tasks will meet manufacturer's specifications without deviation as specified in the Job Sheet CM "A" JS 4.1.2.1, "Servicing the D4D Caterpillar Tractor".

Criterion Test: While working as a member of a team, remove, disassemble, inspect, replace worn parts, assemble, lubricate and adjust power train components of the Caterpillar D4D Crawler Tractor. All tasks are to conform to manufacturer's specifications as specified in the Job Sheet CM "A" JS 4.1.2.1, "Servicing the D4D Caterpillar Crawler Tractor Power Train".

Homework: Read "Operation and Maintenance Instructions", Caterpillar D4D Tractor Form 34887-2, pages 61 - 81.

d. 76-S "Short Cut", Caterpillar Tractor Co., (Color, 20 min.).

e. 9051 "Boss of the Bulldozers", Caterpillar Tractor Co. (Color, 20 min.).

2. Slide Presentation sets

a. CT-25 "Torque Converter", International Harvester Co. (Set of 56 slides).

b. CT-26 "Power Shift", International Harvester Co. (Set of 80 slides).

c. JEGO-1104 "Track Type Tractors", Caterpillar Tractor Co. (Set of 65 slides).

d. JEGO-1106 "Sprocket Removal and Installation", Caterpillar Tractor, Co. (Set of 50 slides).

e. JEGO-1706 "Safety and You", Caterpillar Tractor Co. (Set of 19 slides).

f. JEOO-1601 "Direct Drive Transmission", Caterpillar Tractor Co. (Set of 50 slides).

g. JEOO-1602 "Clutches, Part 1", Caterpillar Tractor Co. (Set of 63 slides).

h. JEOO-1603 "Clutches, Part 2, Caterpillar Tractor Co. (Set of 46 slides).

i. JEOO-1604 "Power Shift", Caterpillar Tractor Co. (Set of 54 slides).

j. JEOO-1606 "Final Drives, Part 1", Caterpillar Tractor Co. (Set of 43 slides).

3. Slides (single).

   a. CM "A" S 4.1.2.1, "D-8 Crawler Tractor w/o Blade"

   b. CM "A" S 4.1.2.2, "MRS-I-110 Wheeled Tractor w/o Attachments".

   c. CM "A" S 4.1.2.3, "I.H.C. Wheeled Tractor w/o Attachments".

   d. CM "A" S 4.1.2.4, "D-7 Crawler Tractor with std. Dozer Blade".

   e. CM "A" S 4.1.2.5, "D-8 Crawler Tractor with Angle Dozer Blade".

   f. CM "A" S 4.1.2.6, "955 Crawler Front End Loader w/std. Bucket".

   g. CM "A" S 4.1.2.7, "MRS-S-110 Scraper with MRS-I-110 Tractor".

   h. CM "A" S 4.1.2.8, "Galion 118-T Motor Grader".

   i. CM "A" S 4.1.2.9, "3 Axle Road Roller".

   j. CM "A" S 4.1.2.10A, "Sheepsfoot Roller (Towed)".

   k. CM "A" S 4.1.2.10B, "Wobbly Wheel Roller (Towed)".

   l. CM "A" S 4.1.2.10C, "Grid Roller (Towed)".

   m. CM "A" S 4.1.2.10D, "Wobbly Wheel Roller (Towed)".

   n. CM "A" S 4.1.2.11, "Crawler Mounted Crane".

o. CM "A" S 4.1.2.12, "Truck Mounted Crane".

p. CM "A" S 4.1.2.13, "Wheeled Mounted Crane".

q. CM "A" S 4.1.2.14, "Air Compressor, 600 CFM, Rotary".

r. CM "A" S 4.1.2.15, "Master Clutch Components".

s. CM "A" S 4.1.2.16, "Master Clutch Brake".

t. CM "A" S 4.1.2.17, "Transmission Gear Arrangement".

u. CM "A" S 4.1.2.18, "Transmission Gearshift Mech.".

v. CM "A" S 4.1.2.19a, b, c, d, e, f, "Transmission Interlock".

w. CM "A" S 4.1.2.20, "Steering Clutch Components".

x. CM "A" S 4.1.2.21, "Steering Clutch Brake Mechanism".

y. CM "A" S 4.1.2.22, "Steering Clutch, Exploded View".

z. CM "A" S 4.1.2.23, "Steering Clutch, Assembly Check".

aa. CM "A" S 4.1.2.24, "Final Drive Operation".

ab. CM "A" S 4.1.2.25, "Final Drive and Cover Assembly".

ac. CM "A" S 4.1.2.26, "Track and Roller Frame Group".

ad. CM "A" S 4.1.2.27, "Track and Roller Frame Lock and Pins".

- ae. CM "A" S 4.1.2.28, "Track and Roller Frame Pins and Links".
- af. CM "A" S 4.1.2.29a, b, "Track and Roller Frame Link and Pins".
- ag. CM "A" S 4.1.2.30a, b, "Track Shoes (Types)".
- ah. CM "A" S 4.1.2.31, "Track Adjustments".
- ai. CM "A" S 4.1.2.32, "Track Roller Lubrication".
- aj. CM "A" S 4.1.2.33, "Track Recoil Mechanism".
- ak. CM "A" S 4.1.2.34, "Track Frame Alignment".

4. Locally Prepared Materials:
    - a. Job sheets.
        - (1) CM "A" JS 4.1.2.1, "Servicing the D4D Caterpillar Tractor".

5. Devices:
    - a. Chassis, Caterpillar D-2 Power Train Assembly, Transmission to Final Drive (Cutaway).

E Training Aids Equipment:

1. 16mm sound movie projector.
2. 35mm slide projector.
3. Overhead projector.

OUTLINE OF INSTRUCTION	INSTRUCTOR ACTIVITY	STUDENT ACTIVITY
I. Introduction to the lesson.		
A. Establish contact.	I.A. Introduce self and topic.	
2. Topic: Construction Equipment Power Trains		
B. Establish readiness.	I.B. Motivate student.	
1. Purpose.		
2. Assignment.		
C. Establish effect.	I.C. Bring out need and value of material being presented.	
1. Value.		
a. Pass course.		
b. Perform better on the job.		
c. Get advanced.		
d. Be a better Construction Mechanic.		
D. Overview:	I.D. State learning objectives. 1. State information and materials necessary to guide student.	

OUTLINE OF INSTRUCTION	INSTRUCTOR ACTIVITY	STUDENT ACTIVITY
II. Presentation.		
A. Types of construction equipment.		
1. Track Laying tractors (Crawler Tractors).	II.A.1. Show slide No. CM "A" S 4.1.2.1, "D-8 Crawler Tractor w/o Blade."	II.A.1. Observe and ask questions.
a. Used for.		
(1) Pioneering work.		
(2) Excavation.		
(3) Backfill.		
(4) Towing attachments:		
(a) Rollers.		
(b) Disks.		
(c) Harrows.		
(d) Water wagons.		
(e) Scrapers.		
(5) Push dozer.		
2. Wheeled tractors.		
a. Used in place of track laying tractor.		
(1) Advantages.		
(a) Speed.		
(b) Greater compaction on fill work.		

OUTLINE OF INSTRUCTION	INSTRUCTOR ACTIVITY	STUDENT ACTIVITY
(2) Types.		
(a) Four wheel drive.	II.A.2.a.(2)(a) Show slide CM "A" S 4.1.2.2, "MRS-I-110 Wheeled Tractor w/o Attachments".	II.A.2.a.(2)(a) Observe and ask questions.
(b) Two wheel drive.	II.A.2.a.(2)(b) Show slide CM "A" S 4.1.2.3, "I.H.C. Wheeled Tractor w/o Attachments".	II.A.2.a.(2)(b) Observe and ask questions.
(3) Used for:		
(a) Pulling scrapers.		
(b) Rollers.		
(c) Plows.		
(d) Lawn mowers.		
(e) Drags.		
(f) Magnetic sweepers.		
3. Bulldozers and Angle Dozers.		
a. Bulldozer (common name).	II.A.3.a. Show slide CM "A" S 4.1.2.4, "D-7 Crawler Tractor with std. Dozer Blade".	II.A.3.a. Observe and ask questions.
(1) Tractor with Dozing blade attachment.		
(a) Blade is at a right angle to tractor frame.		
1. Can raise and lower.		
2. Used for.		
a. Backfill.		

OUTLINE OF INSTRUCTION	INSTRUCTOR ACTIVITY	STUDENT ACTIVITY
b. Land clearing.		
c. Ditch digging.		
d. Building road beds.		
b. Angle dozer (common name).	II.A.3.b. Show slide CM "A" S 4.1.2.5, "D-8 Crawler Tractor with Angle Dozer Blade".	II.A.3.b. Observe and ask questions.
(1) Tractor with dozing blade attachment.		
(a) Blade may be adjusted away from right angle tractor frame.		
(b) Blade can be raised or lowered same as bulldozer.		
(c) Used for:		
1. Same as Bulldozer.		
4. Front End loaders.		
a. Tractor with loading bucket or adjustable forks attached.	II.A.4.a. Show slide CM "A" S 4.1.2.6, "955 Crawler Font End Loader w/std. Bucket".	II.A.4.a. Observe and ask questions.
(1) Types.		
(a) Wheeled.		
(b) Track laying (crawler).		
b. Used for:		
(1) Loading and unloading cargo (forks).		
(2) Bulldozing (4 in 1 bucket).		

OUTLINE OF INSTRUCTION	INSTRUCTOR ACTIVITY	STUDENT ACTIVITY
(3) Scraping (4 in 1 bucket).		
(4) Bucket loading.		
5. Scrapers.		
a. Types.	II.A.5.a. Show slide CM "A" S 4.1.2.7, "MRS-S-110 Scraper with MRS-I-110 Tractor".	II.A.5.a. Observe and ask questions.
(1) Motorized.		
(a) Equipped with a high speed pneumatic tired pulling unit.		
(2) Tractor towed.		
(a) Drawn by a track laying (crawler) tractor.		
b. Used for:		
(1) Moving large volumns of dirt.		
(2) Construction of roads.		
(3) Construction of airfields.		
6. Motor graders.		
a. Types.	II.A.6.a. Show slide CM "A" S 4.1.2.8, "Galion 118-T Motor Grader".	II.A.6.a. Observe and ask questions.
(1) Basically all the same.		
(a) Long bridge type frame supporting engine, blade, two or more driving wheels, various steering and blade controls.		

OUTLINE OF INSTRUCTION	INSTRUCTOR ACTIVITY	STUDENT ACTIVITY
b. Used for:		
(1) Finished grading.		
(a) Air fields.		
(b) Roads.		
(c) Sloping banks.		
(d) Ditching.		
7. Road Rollers.		
a. Types.	II.A.7.a. Show slide CM "A" S 4.1.2.9, "3 Axle Road Roller".	II.A.7.a. Observe and ask questions.
(1) Motorized.		
(a) Tandem.		
1. Rollers filled with water for additional weight.		
2. Powered by a gasoline engine or a diesel engine.		
(b) Used for:		
1. Final surface compaction of roads, airports and other smooth surfaces.		
(2) Towed.		
(a) Sheepsfoot.	II.A.7.a.(2) Show slide CM "A" S 4.1.2.10A, "Sheepsfoot Roller (Towed)".	II.A.7.a.(2) Observe and ask questions.

OUTLINE OF INSTRUCTION	INSTRUCTOR ACTIVITY	STUDENT ACTIVITY
1. Uses tampers (feet) for compaction.		
2. As the surface becomes compacted, the tampers will stay on top of the surface rather than sink into surface.		
3. Newer models may be self propelled.		
4. Used for: a. Compaction of Air fields. b. Compaction of roads. c. Compaction of building sites.		
(b) Wobbly wheel. 1. Wobbly action of the pneumatic tires kneads the surface being compacted. 2. Used for: a. Roads. b. Airfields. c. Building sites.	II.A.7.a.(2)(b) show slide CM "A" S 4.1.2.10B, "Wobbly Wheel Roller (Towed)" and CM "A" S 4.1.2.10D, "Wobbly Wheel Roller (Towed)".	II.A.7.a.(2)(b) Obser and ask questions.

OUTLINE OF INSTRUCTION	INSTRUCTOR ACTIVITY	STUDENT ACTIVITY
(c) Grid.	II.A.7.a.(2)(c) show slide CM "A" S 4.1.10C, "Grid Roller (Towed)".	II.A.7.a.(2)(c) Observe and ask questions.
1. Uses its grid design on outer surface of drum to break up old road material.		
8. Power crane - shovels.		
a. Often called the most versatile piece of construction equipment available due to the many attachments.		
b. Types.	II.A.8.b. Show slides CM "A" S 4.1.2.11, "Crawler Mounted Crane", CM "A" S 4.1.2.12, "Truck Mounted Crane", and CM "A" S 4.1.2.13, "Wheeled Mounted Crane".	II.A.8.b. Observe and ask questions.
(1) Crawler mounted.		
(2) Truck mounted.		
(3) Wheel mounted.		
c. Attachments.		
(1) Crane.		
(2) Shovel.		
(3) Drag line.		
(4) Back hoe.		
(5) Clam shell.		
(6) Pile driver.		
9. Air compressors.		
a. Types.		

OUTLINE OF INSTRUCTION	INSTRUCTOR ACTIVITY	STUDENT ACTIVITY
(1) Reciprocating.		
(2) Rotary.	II.A.9.a.(2) Show slide CM "A" S 4.1.2.14, "Air Compressor, 600 CFM, Rotary".	II.A.9.a.(2) Observe and ask questions.
(3) Screw.		
b. Used for:	II.A.9.b. Take class to field to show actual equipment.	II.A.9.b. Feel free to ask questions on the use of any of the equipment seen.
(1) Inflate rubber equipment.		
(2) Spray paint.		
(3) Operate pneumatic tools.		
(4) Clean equipment.		
(5) Source of power for drilling equipment.		
NOTE: The remaining portion of this topic will cover only the track laying (crawler) tractors.		
B. Track laying tractors (crawler).		
1. Power flow.	II.B.1. Use slide presentation set JEGO-1104 "Track Type Tractors", (set of 65 slides).	II.B.1. Observe slide presentation and ask questions.
a. Master clutch.		
(1) Provides a means of coupling and uncoupling the prime mover (engine) from the power train.		
(2) Transmits power from the prime mover (engine) to the transmission.		

OUTLINE OF INSTRUCTION

(3) Usually located in a compartment in the front portion of the transmission case.

(a) May be a torque convertor.

1. Serves the same function as a master clutch but with the use of hydraulics.

b. Transmission.

(1) Provides the torque or speed advantages as required by the operator.

(2) Provides for operating in:

(a) Forward.

(b) Reverse.

(c) Neutral.

(3) Transmits power to the pinion and bevel gears.

(4) Types.

(a) Sliding gear.

(b) Automatic.

c. Pinion and bevel gears.

(1) Changes direction of torque 90° through the bevel gear shaft to the steering clutches.

INSTRUCTOR ACTIVITY

II.B.1.a.(3) Basic torque convertor will be explained later.

II.B.1.b.(4) Basic automatic transmission will be explained later.

STUDENT ACTIVITY

OUTLINE OF INSTRUCTION | **INSTRUCTOR ACTIVITY** | **STUDENT ACTIVITY**

(2) Provides for an increase in torque and a decrease in speed (gear reduction).

d. Steering clutches.

(1) Allows power from bevel gear shaft to be disengaged from either track for turning.

(a) Eliminates the need for a differential.

(2) Provides a surface for the steering clutch brake.

(3) May be hydraulically assisted for engaged or disengaged.

(4) Transmits torque to the final drive.

3. Final drive.

(1) Final gear reduction in the power train.

(2) Types.

(a) Single reduction.

(b) Double reduction.

f. Drive sprocket.

(1) Sprocket is splined to the final drive gear (called bull gear).

(2) Propells the tractor along the tracks.

OUTLINE OF INSTRUCTION	INSTRUCTOR ACTIVITY	STUDENT ACTIVITY
g. Track roller frame assembly.		
(1) Provides mounting area for:		
(a) Track rollers.		
(b) Track carrier rollers.		
(c) Front idlers.		
(d) Recoil spring.		
(e) Equalizer spring.		
(f) Equalizer bar.		
(2) Supports the weight of the tractor on the tracks.		
h. Tracks.		
(1) Distributes the weight of the tractor over a large area.		
C. Power train components.		
1. Master clutch.		
a. Nomenclature.	II.C.1.a. Show slide CM "A" S 4.1.2.15 "Master Clutch Components".	II.C.1.a. Observe slide and ask questions on points not clear and take notes.
(1) Clutch shaft.		
(a) All components are mounted on or around the clutch shaft.		
(b) Transfers torque through the clutch assembly to universal joint.		

(c) Splined into the clutch hub.

(2) Clutch hub.

(a) Mounted into the pilot bearing and retained in the flywheel.

(b) Clutch hub can rotate independently of the flywheel.

(c) Clutch disc assemblies are splined.

1. Clutch disc assemblies are the driven members of the clutch.

(3) Pressure plates.

(a) Splined to the flywheel.

(b) Driving member of the clutch.

(4) Loading plate.

(a) Slides on clutch shaft.

(b) Pinned to the rear pressure plate (not attached).

(c) Oil pump drive gear bolted to the loading plate.

(5) Adjusting ring and bracket assembly.

(a) Bolted to flywheel.

OUTLINE OF INSTRUCTION | **INSTRUCTOR ACTIVITY** | **STUDENT ACTIVITY**

(b) Provides a mounting for the cam link and roller assembly (roller).

(6) Sliding collar.

(a) Mounted on the loading plate.

(b) Provides a mounting for the cam link and roller assembly (link).

(c) Provides a mounting for the yoke assembly which can turn independently from the collar by the use of a thrust washer and bushing.

b. Operation - master clutch (oil type).

(1) Engaged position.

(a) The over-center action of the cam link and roller assembly against the loading plate holds the pressure plates and driven disc assemblies together, allowing the flywheel, pressure plates, driven disc assemblies and clutch shaft to rotate as a unit.

(2) Disengaged position.

OUTLINE OF INSTRUCTION	INSTRUCTOR ACTIVITY	STUDENT ACTIVITY
(a) The yoke assembly moves the sliding collar assembly away from the clutch loading plate; releasing the over center action of the cam link and roller assembly. With the over center action released, the pressure plates rotate independent of the driven disc assemblies and the clutch shaft can not transmit torque from the flywheel to the transmission input shaft.	II.C.1.b.(2)(a) Show slide presentation JE00-1602 "Clutches, Part 1", Caterpillar Tractor Co. (set of 63 slides).	II.C.1.b.(2)(a) Observe slide presentation and ask questions on items not clear.
c. Clutch brake.	II.C.1.c. Show slide CM "A" S 4.1.2.16 "Master Clutch Brake".	
(1) Purpose:		
(a) To aid in shifting gears by stopping clutch shaft.		
(2) Types.		
(a) Disc; used on older equipment.		
(b) External shoe; used on new equipment.		
d. Maintenance.		
(1) Clutch release bearing and pilot bearing.		
(a) Replace if faulty.		
(2) Driven disc.		

(a) Dry type; replace if warped. Relign or replace if worn or oil soaked.

(b) Oil type; replace if warped or dished in excess of 0.015" worn in excess of 0.025" from new thickness, sintered lining material is chipped in excess of one full land width, cracks are visible at root of teeth, teeth have abnormal wear, disc has foreign material embeded in the disc lining material flaked away in any area larger than a quarter.

(3) Engaging mechanism.

(a) Worn or broken parts may be repaired or replaced as necessary.

(4) Driving plates.

(a) Dry type: worn or broken parts or weak retracting springs may be repaired or replaced as necessary.

(b) Oil type: Replace if worn in excess of 0.020" from new thickness, plate has radical grooves or cracks across the wear face, warped or dished in excess of 0.015" plate has the wear face burned to a blue-black appearance (this requires replacement of mating disc).

II.C.1.d.(4) Oral questions:

a. On the spring engaged clutch, how many driving surfaces are provided by the flywheel?

OUTLINE OF INSTRUCTION

(5) Drive links.

(a) Always replace if worn or broken.

(b) Good practice to replace anytime clutch is out if they haven't been replaced recently.

e. Adjust.

CAUTION!! NEVER ADJUST WITH ENGINE RUNNING!!!

(1) Loosen lock(s) and disengage the clutch.

(2) Turn the adjusting collar or ring clockwise (from rear of machine) to tighten the clutch.

(a) Turn only slightly and test by engaging the clutch.

1. Properly adjusted when a spring scale placed at bottom of handle grip registers pounds of pull, recommended by manufacturer's to snap clutch over-center.

a. Dry type - engine stopped clutch at operating temperature.

b. Oil type - engine stopped, clutch cold.

INSTRUCTOR ACTIVITY

II.C.1.d.(5) Oral questions.

a. By what means or method is clutch free travel obtained?

b. The master clutch of the D4D has how many driven discs?

c. The clutch brake serves what function?

STUDENT ACTIVITY

OUTLINE OF INSTRUCTION	INSTRUCTOR ACTIVITY	STUDENT ACTIVITY
CAUTION!! NEVER START ENGINE UNTIL THE ADJUSTING MECHANISM IS LOCKED SECURELY!!!!		
f. Lubricate.		
(1) Always refer to manufacturer's specifications for proper lubrication type and interval.		
g. Trouble recognition.		
(1) Clutch will not remain in engagement.		
(a) Check for too tight adjustments.		
(b) Cam mechanism worn excessively.		
(2) Clutch vibrates excessively.		
(a) Check run out of plates and discs.		
(b) Improperly balanced on installation.		
h. Inspect.	II.C.1.h. Introduce and show movie MH-10017, "It can Happen", (20 min.).	II.C.1.h. View film and take notes.
(1) Inspect all parts for excess wear, warpage, breaks and cracks.	Review high points of movie.	Participate in instructor guided discussion.
2. Torque converter.		
a. Nomenclature:	II.C.2.a. Show slide set CT-25 "Torque Converter", International Harvester Co., (set of 56 slides).	II.C.2.a. Observe slides and ask questions.
(1) Impeller (pump)		
(a) Driven by engine flywheel.		

(2) Turbine.

(a) Attached to transmission input shaft or convertor output shaft.

(3) Stator.

(a) May be mounted fixed, between the impeller and turbine.

(b) May be mounted on a one way free wheeling clutch between the impeller and turbine.

b. Operation.

(1) Impeller turned by the flywheel, centrifugal force tries to throw oil in the impeller in a straight line; however, because of the curvature of the impeller vanes the oil travels across to the turbine. The force with which it strikes the vanes of the turbine causes the turbine to turn in the same direction as that of the impeller. The oil upon leaving the turbine is moving in the opposite direction of that of the turbine and impeller and if permitted to strike the vanes of the impeller would tend to slow the impeller (engine). The oil is directed to the stator which fits between the outlet of the turbine

OUTLINE OF INSTRUCTION	INSTRUCTOR ACTIVITY	STUDENT ACTIVITY
and the input of the impeller. The stator changes the direction of the oil flow to that of the impeller and turbine. The torque imported to the turbine is used to turn the transmission input shaft.		
3. Sliding gear transmission.		
a. Nomenclature. (1) Since this type of transmission was covered in the preceding phase (Auto Chassis) it will not be duplicated in this phase.	II.C.3.a. Show slide set presentation JE00-1601 "Direct Drive Transmission", Caterpillar Tractor Co. (set of 50 slides). Review and point out the differences of this transmission and the automotive transmission.	II.C.3.a. Observe slides and ask questions.
b. Operation. (1) See instructor activity.	II.C.3.b. Show slides CM "A" S 4.1.2.17 "Transmission Gear Arrangement", CM "A" S 4.1.2 18 "Transmission Gearshift Mech." and CM "A" S 4.1.2 19a, b, c, d, e, and f "Transmission Interlock" to show how 5 forward and 5 reverse gear speeds are obtained.	II.C.3.b. Observe slides and ask questions of the instructor on items not clear.
4. Power shift transmissions. a. International Harvester series. (1) TD-15, TD-20 Crawler tractors and model 175 and 250 loaders have similiar design and identical power flows. (2) Nomenclature.	II.C.4.a. Show slide presentation CT-26 "Power Shift", International Harvester Co. (set of 80 slides).	II.C.4.a. Observe slide presentation and ask questions and take notes.

OUTLINE OF INSTRUCTION	INSTRUCTOR ACTIVITY	STUDENT ACTIVITY
(a) Above equipment power shift transmissions have same amount of shafts and clutches. 1. Shaft assemblies. a. Forward clutch shaft. b. Reverse clutch shaft. c. Spline shaft. d. Bevel pinion shaft. 2. Clutch assemblies. a. Forward clutch shaft - hydraulically actuated for smooth shifting. b. Reverse clutch shaft - Hydraulically actuated for smooth shifting.		
(3) Operation.		
(a) These transmissions provide four speed ranges in forward and reverse. All shifts with the exception of the high-low range are hydraulically actuated and all gears are in constant mesh with the exception of the high-low range sliding gear.	II.C.4.a.(3)(a) Review slide presentation.	II.C.4.a.(3)(a) Ask questions; take notes on material presented.

OUTLINE OF INSTRUCTION	INSTRUCTOR ACTIVITY	STUDENT ACTIVITY
b. Caterpillar power shift, D-8H series. (1) Nomenclature. (a) This transmission consists of five sets of planetary gear systems. 1. Each system has a hydraulically actuated clutch. (b) Three forward and three reverse speeds are available. 1. Selection and direction is accomplished by positioning spool valves in the transmission hydraulic controls within the upper compartment of the transmission.	II.C.4.b. Use slide presentation JE00-1604 "Power Shift", Caterpiller Tractor Co. (set of 54 slides).	II.C.4.b. Observe slides, take notes as required and ask questions.
(2) Operation. (a) Power from the engine is transmitted by the flywheel to the torque divider through the torque divider to the output shaft to the universal joint to the input shaft of the power shift transmission. Then through two of the five planetary gears systems depending on the position of the spool valve to obtain desired speed and direction. The transmission	II.C.4.b.(2) Use Caterpillar meeting guide #33 to trace power flow.	II.C.4.b.(2) Ask questions if required.

output shaft is splined to a transfer gear within the transfer case. The transfer gear drives the bevel pinion which in turn drives the bevel gear, to the steering clutches, to the final drives to the tracks.

c. Repair procedure.

(1) Transmission housing.

(a) Provides an oil reservoir for transmission and bevel gear compartment.

(b) Machined to hold shaft and bearing in proper alignment.

(c) Replace seals and gaskets.

(d) Inspect for cracks and leaks.

(2) Bearings, types.

(a) Ball bearings.

1. Check for wear or damage.

(b) Tapered roller bearings.

1. Check for wear or damage.

2. Preload when installing.

3. Adjust to manufacturer's specifications.

OUTLINE OF INSTRUCTION | **INSTRUCTOR ACTIVITY** | **STUDENT ACTIVITY**

(c) Straight roller bearings.

1. Check for wear or damage.

2. Install if not damaged.

(3) Gears and shafts.

(a) Check for wear and damage.

(b) Install gears properly to obtain proper gear ratio.

(c) Install correct spacers.

(4) Shifting mechanism.

(a) Check forks and shafts for wear or warped condition.

(b) Check interlock mechanism for wear or damage.

(5) Common failures.

(a) Transmission jumps out of gear.

1. Inoperative interlock mechanism.

2. Worn or broken gear teeth.

3. Sprung or broken shifter forks.

(b) Worn or broken gears and bearings.

1. Lubricant, low-main cause of transmission failure.

2. Foreign matter, dirt, etc.

3. Inoperative clutch brake.

(6) Lubricating system.

(a) Splash system.

1. Rotating gears throw oil around giving lubrication to gears and bearings.

2. May have an oil trough to catch and direct oil to certain gears and bearings.

(b) Force feed.

1. Pump provides volume of oil into restricted passages creates pressure.

2. Oil is directed to shaft and gear bearings.

3. Oil is directed to spray manifold for lubrication of gear teeth on some transmissions.

(7) Lubricating systems, common failures.

(a) Splash system.

1. Improper lubricant.

2. Insufficient lubricant.

(b) Force feed.

1. Improper lubricant.

2. Insufficient lubricant.

3. Worn or damaged pump.

(8) Power shift transmissions.

(a) Only qualified specialists will repair these transmissions.

5. Steering clutches.

a. Function, types, nomenclature and construction.

(1) Function.

(a) To disengage power from either track for turning.

(b) Eliminate the need for differential gears.

(c) To aid in operating.

(2) Types.

(a) Dry multiple disc.

1. Spring loaded.
2. Mechanically released.

(b) Wet multiple disc.

1. Spring loaded.
2. Hydraulically released.

(c) Most steering clutches are similar in design.

(3) Nomenclature and construction

II.C.5.a.(3) Show slides CM "A" S 4.1.2.20, "Steering Clutch Components", and CM "A" S 4.1.2.22, "Steering Clutch Exploded View".

(a) Hub (inner drum).

1. May be splined to the steering clutch shaft or bolted to the steering clutch shaft flange.
2. Splines on the outside that engage the driving plates.

(b) Driving plates.

1. Internal teeth.
2. Mesh with the teeth on the steering clutch hub.
3. Usually are unlined.

(c) Driven disc.

1. External teeth.

2. Mesh with the internal teeth of the steering clutch drum.

3. Driven discs are usually lined with a bimetallic or molded type of lining bounded to the disc.

(d) Drum.

1. Splined on the inside with a smooth outside.

2. Provides a surface for steering clutch brake.

3. Connected to final drive pinion flange.

(e) Plates.

1. Driving plate is cast with the hub.

2. Pressure plates held in drum by springs.

(f) Springs.

1. One to eight sets of springs hold clutch in engaged position.

2. Springs are further compressed as plates are forced apart to disengage the clutch.

(g) Brake.

1. External, contracting band design.

    a. Self energizing.

2. Used to stop steering clutch drum from turning after the steering clutch has been disengaged for a pivot turn or to slow steering clutch drum for a quicker change of direction than can be made with just the steering clutch disengaged.

3. May be used as a parking brake.

(4) Steering clutch service.

(a) Method of removal.

1. If clutch hub is splined to bevel gear shaft, both clutches and the bevel gear must be removed as an assembly.

2. If clutch hub is bolted to the steering clutch shaft flange, either clutch or the bevel gear may be removed individually.

3. Brake may be replaced without removing the clutch assembly.

(b) Disassembly.

1. If a clutch hub is splined to bevel gear shaft back retaining nut off ONLY two or three threads so that it can catch the clutch assembly as it breaks loose from the splines.

2. Use proper tools to compress clutch springs for removal and installation of spring keepers, otherwise clutch parts may be damaged or personnel injured.

(c) Inspection and repair.

1. Check for worn or scored disc, renew if necessary.

   a. If unlined member has been warm enough to cause blue spots or heat checks, it should be replaced.

   b. If unlined member is dished or warped it should be replaced.

   c. If lined member has cracked or gouged out lining it should be replaced.

OUTLINE OF INSTRUCTION	INSTRUCTOR ACTIVITY	STUDENT ACTIVITY

d. If lined member of a dry type clutch is oil soaked or has grease on it, it should be replaced.

e. If teeth or either lined or unlined members show abnormal wear or have cracks at the roots of the teeth, they should be replaced.

f. If lined or unlined members are worn excessively, they should be replaced.

2. Check splines on hub and in drum for burr; dress down if damaged.

II.C.5.a.(4)(c)2. Show slide CM "A" S 4.1.2.23, "Steering Clutch, Assembly Check".

a. If burred or dented only slightly, dress down and reuse. If damaged sufficiently to cause member to hang, replace.

3. Check splined shaft for burrs and foreign matter.

a. If burred slightly, dress down and reuse.

b. If hammered from operating while loose, replace.

OUTLINE OF INSTRUCTION **INSTRUCTOR ACTIVITY** **STUDENT ACTIVITY**

4. Check springs for proper tension or breakage; renew if necessary.

   a. Some manufacturers give free length, some give length for a certain pressure, if no specs are available, compare with a new spring.

5. Check release bearing.

   a. Replace if worn or damaged.

   b. Insure bearing is installed with thrust side in proper relation to tractor.

6. Check measurements of disc in accordance with manufacturer's specifications.

   a. Some clutches checked by measuring each member individually.

   b. Some clutches checked for overall thickness when assembled.

7. Check the following items before replacing the clutch.

a. Seals and gaskets.

b. Check the unit for proper assembly.

(d) Installation.

1. Back brake band support screw out before installation.

2. Insure bevel gear is on proper side of bevel pinion.

3. Insure back lash is maintained between bevel and pinion on installation.

(e) Adjustments.

1. Back lash.

a. If bevel gear was removed, back lash must be readjusted.

2. Steering clutch lever free travel booster spring, clutch lever bumper stop, etc.

(f) Steering clutch brakes.

II.C.5.a.(4)(f) Show slide CM "A" S 4.1.2.21, "Steering Clutch Brake Mechanism".

1. Types.

a. External, contracting band type.

b. Self-energizing.

c. May be WET or DRY type.

2. Function.

a. Used to stop steering clutch drum from turning after the steering clutch has been disengaged for a pivot turn or to slow steering clutch drum for a quicker change of direction than can be made with just the steering clutch disengaged.

b. May be used as a parking brake.

3. Maintenance and repair.

a. Adjust.

b. Reline or replace.

1. If worn excessively, oil soaked (dry type, cracked out from rivet holes or has loose rivets).

4. Adjustments.

a. Adjust linkage free travel.

b. Adjust brake band.

II.C.5.a.(4)(f)4. Introduce and show slide presentation JE00-1603, "Clutches, Part 2", Caterpillar Tractor Co. (set of 46 slides).

II.C.5.a.(4)(f)4. Observe slide presentation, take notes and ask questions.

OUTLINE OF INSTRUCTION	INSTRUCTOR ACTIVITY	STUDENT ACTIVITY
1. Compensates for normal lining wear.	II.C.5.a.(4)(f)4. Show slide CM "A" S 4.1.2.21, "Steering Clutch, Brake Mechanism".	
2. Adjust brake band support screw.	Introduce and show slide presentation JEGO-1706, "Safety and You", (set of 19 slides).	Observe slide presentation, take notes and ask questions.
3. Adjust to manufacturer's specifications.		
4. Properly adjusted, it prevents unnecessary wear at top of band.	Introduce and show movie MN8146, "The Gamblers", Caterpillar Tractor Co. (Color, 20 min.).	View movie and take notes.
	Review high points of movie.	Participate in instructor guided discussion.
	Issue Job Sheet CM "A" JS 4.1.2.1, "Servicing the D4D Caterpillar Tractor".	
	Take class to shop.	
	Introduce students to shop and issue tool chest keys.	Inventory tool chest.
	Direct, supervise and evaluate student performance in the removal, disassembly, inspection, assembly, installation and adjustment of the master clutch, the transmission and the steering clutches.	Remove, disassemble, inspect, assemble, install and adjust th master clutch, transmission and the stee clutches in accordanc with manufacturer's specifications as specified in Job she

OUTLINE OF INSTRUCTION	INSTRUCTOR ACTIVITY	STUDENT ACTIVITY
NOTE: The final drive and sprocket is the last gear reduction in the power train; it is housed in separate compartments. These units have important seals which require special adjustments and are similar in function on all tractors but methods of removing, repairing and adjusting differ on various pieces of equipment.		
6. Final drive and sprocket.	II.C.6. Use cutaway D-2 Caterpillar to show and explain final drive components.	II.C.6. Observe instructor discussion and take notes.
a. Functions of the final drive.	II.C.6.a. Show slide CM "A" S 4.1.2.24 "Final Drive Operation".	
	Introduce and show slide presentation JEOO-1606, "Final Drives, Part 1", Caterpillar Tractor Co. (set of 43 slides).	Observe and take notes.
(1) Increases torque.		
(2) Transmits power from the steering clutches to the track via the sprocket.		
b. Types of gears.		
(1) Spur gears.		
(2) Single or double reduction.		
c. Construction.		

OUTLINE OF INSTRUCTION | **INSTRUCTOR ACTIVITY** | **STUDENT ACTIVITY**

(1) Pinion.

(a) Secured to the final drive pinion shaft.

(b) Drives the main gear or bull gear.

(2) Main gear (bull gear).

(a) Mounted on sprocket shaft (dead axle) utilizing tapered roller bearings.

(b) Sprocket is attached to the hub of the main gear.

II.C.6.c.(2) Show slide CM "A" S 4.1.2.25 "Final Drive and Cover Assembly".

(3) Sprocket.

(a) Propels the tractor along the tracks.

(4) Dead axle (Sprocket shaft, Caterpillar) (pivot shaft IHC).

(a) Is usually pressed into tractor housing.

(b) Very seldom necessary to remove.

(5) Bearings.

(a) Tapered roller bearings.

1. Requiring a prescribed adjustment.

OUTLINE OF INSTRUCTION

(6) Seals.

(a) Earlier tractors.

1. Bellows type (Caterpillar).

2. Metal seal ring (IHC).

d. Repair and adjustment procedures for:

(1) Final drive pinion.

(a) Removed with final drive pinion flange and shaft (OLDER D-4).

(b) Removed with pinion shaft and cage assembly after pulling flange from pinion shaft (NEWER D-4).

(c) Inspect gear for worn or chipped teeth and replace if necessary.

(d) Inspect seals.

(e) No adjustment provided.

(2) Main gear (bull gear).

(a) Removed from dead axle with hub attached.

(b) Inspect inner tapered roller bearing and hub and bull gear repair or replace if necessary.

INSTRUCTOR ACTIVITY

II.C.6.d. Oral questions.

1. Explain function of final drive.

2. What type gears are used in final drive?

3. What is meant by "Single or double reduction"?

4. Describe power flow from final drive pinion to sprocket.

STUDENT ACTIVITY

OUTLINE OF INSTRUCTION

(3) Sprocket.

(a) Caution!! Insure nut is replaced on bull gear hub before pulling sprocket with caterpillar service press.

1. Leave 1/4 inch between nut and sprocket.

(b) Inspect sprocket for cracks and burrs on splines.

(4) Bearings.

(a) Preload main gear bearings according to manufacturer's manual.

(b) Inspect and repair as needed.

(5) Seals.

(a) Earlier tractors.

1. Replace if bellows, (Caterpillar) diaphragm (IHC) is defective.

a. Good practice to replace each time final drives are disassembled if they haven't been replaced recently.

INSTRUCTOR ACTIVITY

II.C.6.d.(3) Introduce and show slide presentation JEGO-1106, "Sprocket Removal and Installation, Caterpillar Tractor Co. (set of 50 slides).

STUDENT ACTIVITY

II.C.6.d.(3) Observe and take notes.

OUTLINE OF INSTRUCTION	INSTRUCTOR ACTIVITY	STUDENT ACTIVITY
b. Cork or leather seals and gaskets may be replaced if bellows (diaphragm) is reusable.		
(b) Later tractors.		
1. Replace if mating faces of either metal ring hasn't got a mirror finish. DO NOT mix sets of seal rings, they are mated at factory.		
2. Replace if mating face of metal rings is contacting on 50% or more of surface from O.D. to I.D.	II.C.6.d.(5)(b)2. Direct, supervise and evaluate student performance in the removal inspection, installation and adjustment of sprocket and final gear hub assembly.	II.C.6.d.(5)(b)2. Remove, inspect, install and adjust sprocket and final drive gear hub assembly in accordance with manufacturer's specifications as specified in the job sheet.
NOTE: Bevel gears and pinions in crawler tractors are much larger than those in automotive equipment, but require the same precision adjustments and care. You have studied the adjustments for bevel gears and pinions in automotive power trains the same adjustments are required in crawler tractors power trains, but new methods and different procedures for determining and making the adjustments will be covered here.		
7. Bevel gear and pinion service.		
a. Function of bevel gear and pinion.		II.C.7.a. Follow instructor lecture and take notes.
(1) Change direction of torque.		

OUTLINE OF INSTRUCTION | INSTRUCTOR ACTIVITY | STUDENT ACTIVITY

(2) Increase torque and decrease speed.

b. Types most commonly used on crawler tractors.

(1) Spur bevel.

(a) Noisy.

(b) More apt to damage a tooth or teeth.

(2) Spiral bevel.

(a) Quieter.

(b) More than one tooth in contact.

c. Repair procedure.

(1) Check carrier runout.

(a) Check bevel gear runout (wobble).

(2) Replacement of bevel gear and pinion.

(a) Replace if teeth are worn excessively or broken or if bevel gear runout is excessive.

1. If matched set, replace as a unit.

a. Otherwise, replace individually.

b. Replace bearings as necessary.

(3) Replace seals.

(a) Anytime oil leaks are excessive.

(b) Good practice to replace all seals each time bevel gear compartment is opened.

d. Adjustments.

(1) Bearing preload (adjusted by spanner nut or shims).

(a) Tighten bevel gear bearings down to manufacturer's specifications and back off (if required) as manufacturer requires.

1. Insure back lash is maintained between pinion and bevel gear.

(2) Pinion depth (adjusted by shims).

(a) Use gage if available or get heel to heel alignment between pinion and bevel gear.

1. This is a starting point only.

(3) Back lash (adjusted by spanner nut or shims).

OUTLINE OF INSTRUCTION **INSTRUCTOR ACTIVITY** **STUDENT ACTIVITY**

(a) Adjusted at point of tightest contact on most equipment.

(b) Move bevel gear closer to or away from pinion gear until back lash is within manufacturer's specifications.

1. Spanner nuts - loosen nut on side of bevel gear must move to, being sure to note amount loosened then tighten other spanner nut same amount (to maintain bearing preload).

2. Shims - remove a few shims from side of bevel gear must move to. Then install these shims on other side of bevel gear (to maintain bearing preload).

(4) Tooth contact pattern.

(a) Smear Prussian blue on teeth of bevel gear and walk pinion gear thru the Prussian blue. Prussian blue will be wiped away at point of contact.

(b) Compare contact pattern with manufacturer's desired pattern and adjust pinion depth as necessary.

OUTLINE OF INSTRUCTION	INSTRUCTOR ACTIVITY	STUDENT ACTIVITY
1. If pinion depth is changed be sure to readjust back lash.	II.C.7.d.(4)(b)1. Take class to shop.	
	Direct, supervise and evaluate student performance in the installation and adjustment of bevel gear and steering clutch assembly.	Install and adjust bevel gear and steering clutch assembly in accordance with manufacturer's specifications as specified in the job sheet.
8. Track roller frame assembly. NOTE: We will remove, inspect and replace the track roller frame assembly which is the largest component of the crawler tractor power train. Most of the work that is performed on the crawler tractor is performed on this component.	II.C.8. Show slide CM "A" S 4.1.2.26 "Track and Roller Frame Group".	
a. Nomenclature and functions of parts.	II.C.8.a. Using cutaway chassis of caterpillar D-2 roller frame assembly explain meaning of technical words and phrases basic components and mechanical principles.	II.C.8.a. Follow instructor discussion and take notes.
(1) Track assembly.		
(a) Link or rail assembly.		
(2) Links.	II.C.8.a.(2) Show slides CM "A" S 4.1.2.27 "Track and Roller Frame Lock and Pins", CM "A" S 4.1.2.28 "Track and Roller Frame Pins and Links", and CM "A" S 4.1.2.29a, b, "Track and Roller Frame Link and Pins".	
(a) Each link overlaps preceeding link.		
(b) Links counterbored to accomodate end of bushing.		

(3) Pins.

(a) Master pin for separating track.

1. Can be identified by a different machined shape on the end of later tractors or plugs in the on earlier tractors.

(b) Standard pin for connecting the links.

(4) Bushings.

(a) Master bushing for separating track.

1. Shorter.

a. Requires collars to fit counterbore of master link.

(b) Standard bushing provides a reaction member for the sprocket teeth to catch and propel the tractor along the track.

(5) Seals.

(a) Two dish shaped washers are found at each end of the bushings in the link counterbores on late model tractors (Caterpillar).

OUTLINE OF INSTRUCTION

(6) Track shoes.

- (a) Distribute weight of tractor over large area of ground.
- (b) Grousers for better traction.
  - 1. Ice grousers.
  - 2. Dirt grousers.
  - 3. Street plates.
  - 4. Flat shoes.
  - 5. Rubber shoes.

(7) Track roller frame assembly and components.

- (a) Track roller frame.
  - 1. Provides a mounting for:
    - a. Track carrier rollers.
    - b. Front idlers.
    - c. Track rollers.
    - d. Recoil springs.
    - e. Equalizer springs.
    - f. Diagonal brace.

INSTRUCTOR ACTIVITY

II.C.8.a.(6) Show slides CM "A" S 4.1.2.30a, b, "Track Shoes (Types)".

II.C.8.a.(7) Using Caterpillar D4D crawler tractors in shop, point out and explain wear and maintenance points.

STUDENT ACTIVITY

II.C.8.a.(7) Observe instructor guided discussion and take notes.

OUTLINE OF INSTRUCTION | INSTRUCTOR ACTIVITY | STUDENT ACTIVITY

2. Carries weight of tractor to rollers.

3. Pivots to allow each track to move up or down independent of the other.

4. Track carrier rollers.

   a. Supports weight of track between sprocket and front idlers.

5. Front idler.

   a. Guides track into position in front of track rollers.

6. Track roller.

   a. Distributes tractor weight along length of tracks.

   b. Guide the track

7. Recoil springs.

   a. Recoils to avoid overstressing the track.

   b. Normally spring tension is not exerted on tracks.

OUTLINE OF INSTRUCTION	INSTRUCTOR ACTIVITY	STUDENT ACTIVITY
8. Equalizer springs or track roller frame support.		
a. Supports front of tractor.		
b. Transfers weight to track roller frame.		
c. Pivots as tracks move up or down (equilizer spring only).		
9. Auxiliary spring "CAT" only.		
a. Forms saddle for equalizer spring.		
b. Permits equalizer spring to pivot.		
10. Diagonal brace.		
a. Keeps track roller frame in alignment.		
b. Maintenance and adjustment, track assembly.	II.C.8.b. Introduce and show movie 76-S, "Short Cut", Caterpillar Tractor Co. (Color, 20 min.).	II.C.8.b. Observe and take notes.
(1) Track removal.		
(a) Loosen track adjustment.	Discuss high points.	
(b) Position master pin at center of front idler.		
(c) Place 12" block at grouser of shoe below master pin.		

OUTLINE OF INSTRUCTION | **INSTRUCTOR ACTIVITY** | **STUDENT ACTIVITY**

(d) Drive tractor forward to bring all slack to top of track.

(e) Remove master pin.

(f) Remove track.

(2) Turning pins and bushings.

(a) Press out pins and bushings.

(b) Install pins and bushings, turning 180° if wear is determined to be excessive by shop supervisor.

(3) Replacing damaged link not adjacent to master link.

(a) Remove shoe from broken link.

(b) Press pins out of both ends of the broken link.

(c) Cut the broken link in two.

(d) Cut a 5/8 inch section out of the bushing.

(e) Remove pieces of link and bushing.

(f) Press two new links on the track.

(g) Install a standard track pin in the two new links.

OUTLINE OF INSTRUCTION | **INSTRUCTOR ACTIVITY** | **STUDENT ACTIVITY**

(h) Install a master bushing in the two new links.

(i) Install collars in the counterbore of the mating links and press in either a master or standard pin.

(4) Adjustment:

II.C.8.b.(4) Show slide CM "A" S 4.1.2.31, "Track Adjustments".

(a) Adjust to obtain 1 1/2 inch clearance between track and carrier roller on earlier tractors, and a 1 inch to 1 1/2 inch sag of track between carrier roller and front idler on later tractors. Be sure to move tractor backward and forward several times to equalize adjustment before checking measurement.

(5) Track roller frame assembly, removal.

(a) Track carrier assembly (bracket and roller).

1. May be removed from the tractor without separating the track by inserting a 4" x 4" block or 3" to 4" piece of pipe between track and sprocket at top and move tractor back until track clears roller.

(6) Removal of front idler.

(a) Front idler.

1. Separate track.

2. Remove capscrews securing idler arms to end collar bearings.

3. Loosen the wear plate spring adjusting capscrews in each end of collar bearing.

4. Pull idler forward off of track roller frame.

(7) Track rollers, removal.

(a) May be removed from tractor without separating track chain by raising track frame enough to allow roller to pass between track frame and chain.

(b) Loosen track enough to allow roller to pass between track frame and chain.

(c) Remove capscrews securing roller shaft to track frame.

(d) Remove roller assembly.

(e) Install in reverse order of disassembly.

OUTLINE OF INSTRUCTION	INSTRUCTOR ACTIVITY	STUDENT ACTIVITY
(f) Lubrication.	II.C.8.b.(7)(f) Show slide CM "A" S 4.1.2.32 "Track Roller Lubrication".	
(8) Recoil mechanism.	II.C.8.b.(8) Show slide CM "A" S 4.1.2.33 "Track Recoil Mechanism".	
(a) May be removed without separating track by placing block between rear of front idler and web of track frame.		
(b) Loosen track adjustment as much as possible.		
(c) Remove the outside front idler arm.		
(d) Remove the recoil spring guides.		
(e) Remove recoil spring from bracket.		
NOTE: If recoil spring bolt is broken, all of spring tension will be exerted on track and spring must be compressed before track can be separated and spring removed.		
(9) Equalizer mechanism, removal.		
(a) Remove nuts securing shackle bolts to engine block on models with auxiliary spring. Remove bolts securing saddle to frame on models without auxiliary spring.		
(b) Remove spring clip from one end of spring.		

OUTLINE OF INSTRUCTION

(c) Raise front of tractor until bottom of oil pan is a little higher than top of spring.

(d) Raise end of spring, that clip was removed from, until it clears the front idler arm. Move spring over top of idler arm until other end clears its clip.

(e) Remove spring from tractor.

(f) Install in reverse order of disassembly.

(10) Auxiliary spring.

(a) Remove nuts from U-bolts securing auxiliary spring to equalizer spring.

(b) Remove pins securing auxiliary spring to shackles.

(c) Remove auxiliary spring from tractor.

(d) Auxiliary spring may be removed as a unit with equalizer spring.

(11) Track roller frame, assembly, removal.

INSTRUCTOR ACTIVITY

II.C.8.b.(11) Maintain class interest by using oral questions.

1. What is the purpose of the master pin?

STUDENT ACTIVITY

II.C.8.b.(11) Answer questions as called on by instructor.

OUTLINE OF INSTRUCTION	INSTRUCTOR ACTIVITY	STUDENT ACTIVITY
	2. Describe the procedure for adjusting tracks. 3. Explain briefly the difference between a master pin and a standard pin. Take class to shop.	
(a) Separate the track.		
(b) Remove diagonal brace bearing cap.		
(c) Remove capscrews securing sprocket outer bearing cage support to the track frame.		
(d) If equipped with oscillating track frame.		
1. Remove the equalizer spring clip.		
2. Raise rear of tractor and equalizer spring enough to clear diagonal brace.		
3. Roll track frame forward.	II.C.8.b.(11)(d)3. Direct, supervise and evaluate student performance in removal of track chain and roller frame assembly --- inspection of track, rollers, front idler, pin and bushings for wear and damage, reassembly of track assemblies, and adjustment.	II.C.8.b.(11)(d)3. Remove track chain and roller frame assembly. Inspect track rollers idler rollers, front idler, pins and bushings, for wear and damage, reassemble and adjust according to manufacturer's specifications in the job sheet.

OUTLINE OF INSTRUCTION	INSTRUCTOR ACTIVITY	STUDENT ACTIVITY
	II.C.8.b.(11)(d)3.(Cont'd) Direct, supervise and evaluate student performance in making final adjustments to D4D crawler tractor, conducting prestart checks, starting and operating the tractor to check accuracy of adjustments made to the machine.	II.C.8.b.(11)(d)3.(Cont'd Make final adjustment to D4D crawler tractor, conduct prestart checks, start and operate the tractor to check accuracy of adjustments made to the machine. All performances to be in accordance with manufacturer's specifications as specified in the job sheet.
(12) Parallel alignment of track frame assembly. (a) Accomplished by adding or removing shims at front idler.	II.C.8.b.(12) Show slide CM "A" S 4.1.2.34 "Track Frame Alignment".	
III. Application.		
A. While working as a member of a team the student removed, disassembled, inspected, replaced worn parts, assembled, lubricated and adjusted the power train of the D4D crawler tractor. All tasks were completed as they were covered in the instructor guide and conformed to manufacturer's specifications as specified in job sheet, CM "A" JS 4.1.2.1.	III.A. Directed, supervised and evaluated student performance or service procedures on the Caterpillar D4D crawler tractor, practical work was covered immediately after information was given in instructor guide.	III.A. While working a a member of a team removed, disassembled, inspected, replaced worn parts, assembled lubricated and adjusted the power train of the Caterpillar D4D Crawler tractor. All tasks were completed as they were covered in the instructor guide and conformed to manufacturer's specifications as specified in the job sheet.

OUTLINE OF INSTRUCTION	INSTRUCTOR ACTIVITY	STUDENT ACTIVITY
IV. Summary.		
A. Types of construction equipment.		
B. Track laying tractors (crawler).		
C. Power train components.	IV.C. Time permitting, show movies ROL-002 "Roll of Drums", Caterpillar Tractor Co. (Color, 20 min.), and 9051, "Boss of the Bulldozers", Caterpillar Tractor Co. (Color, 20 min.).	
V. Test: None.		
VI. Assignment.		
A. Read:	VI.A. Pass out text TD20, Crawler Tractor, Form OM-TD20B,IHC.	VI.A. Read assignment as directed by instructor.
1. Operator's Manual TD20, Crawler, Form OM-TD20B-IHC, pp. 35 - 39.	VI.A.1. Write assignment on chalkboard.	

NAVAL CONSTRUCTION TRAINING CENTER
PORT HUENEME, CALIFORNIA 93043
CONSTRUCTION MECHANIC "A" SCHOOL TRAINING COURSE A-610-0022

Classification: Unclassified

Topic: Adjustment of International Model 260 Power Control Unit

Average Time: 2 Periods (Class), 2 Periods (Pract)

Instructional Materials:

A. Texts:

1. Service Training Outline, Power Control Units, Models 260, 270 and 280, Melrose Tech. Course TE-4, IHC, Construction Equipment Division, 401 North Michigan Avenue, Chicago, Illinois 60611, pp. 1 - 10 and 53 - 64.

2. Service Manual International Power Control Units, Form ISS-1513, International Harvester Co., 401 North Michigan Avenue, Chicago, Illinois 60611, Sec. 2, pp. 1 - 12.

3. Operator's Manual, TD20 Series "B" Crawler Tractor and Tractor Equipment, Form OM-TD20B, International Harvester Co., 401 North Michigan Avenue, Chicago, Illinois, Sec. 9, pp. 25 - 28.

B. References: None.

C. Tools, Equipment and Materials:

1. Tools:

Terminal Objective: Upon completion of this unit each student will be able to service the power train and chassis units of the Caterpillar D4D Crawler Tractor. Using appropriate handtools, special tools, shop equipment and Oxy-Mapp gas outfit, he will remove, disassemble, inspect and replace worn parts, assemble and adjust the master clutch, transmission, steering clutches, final drive/sprocket assembly, bevel gear assembly, and track roller frame assembly. All tasks will meet manufacturer's specifications without deviation as specified in Job Sheets CM "A" JS 4.1.1.1, "Oxy-Mapp Gas Heating and Cutting" and CM "A" JS 4.1.1.2, "Servicing the D4D Caterpillar Crawler Tractor Power Train". Adjust the International 260 Cable Control Unit using appropriate handtools and shop equipment. All adjustments will conform without deviation to manufacturer's specifications as specified in the Job Sheet CM "A" JS 4.1.3.1, "Adjusting International Model 260 Cable Control Units".

Enabling Objectives: Upon completion of this topic each student will be able to adjust the International Model 260 Power Control Unit using appropriate handtools and shop equipment. All adjustments will conform to manufacturer's specifications without deviation as specified in Job Sheet 4.1.3.1, "Adjusting the International Model 260 Power Control Unit".

a. Heavy equipment handtools.

b. Heavy equipment shop tools and equipment.

2. Equipment:

a. Major.

(1) International Model 260 Power Control Units (4 each).

3. Materials:

a. Cleaning solvent.

b. Wiping rags.

c. Gear oil.

D. Training Aids and Devices:

1. Films.

a. MN-8146, "The Gamblers" (20 min.).

2. Slides.

a. International Harvester Strip Film TE-4, Power Control Units.

b. International Harvester Power Control Units SC8620C (80 frame).

3. Locally Prepared Material.

a. Job Sheet.

(1) CM "A" JS 4.1.3.1, "Adjusting the International Model 260 Power Control Unit.

Criterion Test: Adjust the International Model 260 Power Control Unit to conform to manufacturer's specifications without deviation as specified in Job Sheet.

Homework: Study:

1. Service Manual International Power Control Units Form ISS1513, Section 2, pp. 1 - 12.

2. Operator's Manual, TD20, Series "B" Crawler Tractor and Tractor Equipment Form OM-TD20B, Section 9, pp. 25 - 28.

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4. Devices.

   a. International 260 Power Control Unit (Cutaway).

E. Training Aids Equipment:

   1. 16mm sound movie projector.

   2. 35mm slide projector.

OUTLINE OF INSTRUCTION	INSTRUCTOR ACTIVITY	STUDENT ACTIVITY
I. Introduction to the lesson.		
A. Establish contact.	I.A. Introduce self and topic.	
1. Name:		
2. Topic: Adjustment of International Model 260 Power Control Unit.		
B. Establish readiness.	I.B. Motivate student.	
1. Purpose.		
2. Assignment.		
C. Establish effect.	I.C. Bring out need and value of material being presented.	
1. Value.		
a. Pass course.		
b. Perform better on the job.		
c. Get advanced.		
d. Be a better Construction Mechanic.		
D. Overview.	I.D. State learning objectives.	
	a. State information and materials necessary to guide student.	

OUTLINE OF INSTRUCTION

II. Presentation.

- A. Power Control Units (International Model 260 and 260S).
  - 1. Principles of operation and construction.
    - a. Planetary system.
      - (1) Sun gear.
        - (a) Attached to drive shaft by a spline.
        - (b) Meshes with two planet gears.
      - (2) Planet pinion.
        - (a) Installed on pins in the cable drum.
        - (b) Mesh with internal teeth of ring gear.
      - (3) Ring gear.
        - (a) Bolted inside the clutch housing.
    - b. Spooling.
      - (1) Sun gear turns whenever the tractor power take-off shaft is in operation.

INSTRUCTOR ACTIVITY

II.A.1. Pass out texts:
a. Service Manual International Power Control Units.
b. Operator's Manual TD-20B International Crawler Tractor and Equipment.

II.A.1.b. Have class refer to illustrations in service manual International Power Control Units pp. 1, sec. 2.

STUDENT ACTIVITY

II.A.1.b. Open texts to pages directed by instructor and follow discussion.

(2) The housing and ring gear cannot rotate when the friction band is applied to the clutch housing.

(3) The stationary ring gear forces the two planet gears to travel around inside the ring gear and drive the cable drum in a spooling direction.

c. Holding.

(1) When the friction band is applied to the brake housing, it holds the cable drum firmly and keeps the loaded cable taut.

(2) Then planet gears spin on their own axis and cause the ring gear and clutch housing to rotate.

d. Unspooling.

(1) When the friction band is released from the drums, the planet gears and cable drums rotate in the unspooling direction.

(2) The ring gear with the clutch housing rotates in the same direction.

(3) The sun gear continues to turn in its usual direction.

e. Lock out.

(1) Same as unspooling except the control lever remains to the extreme right of the operator holding the brake and clutch band released from the brake drum and clutch housing.

f. Brake and clutch bands.

(1) Brake and lower clutch bands can be turned end for end and be interchanged.

(2) Upper clutch band, bi-mettalic tips, not interchangeable.

2. Maintenance and repair.

a. Replacement of clutch and brake band.

NOTE: It is not necessary to remove the power-control unit from the tractor when replacing the brake and clutch bands, also, the bands can be removed and replaced without removing the drums.

b. Adjustments.

CAUTION: BEFORE MAKING ANY ADJUSTMENTS, STOP THE ENGINE AND BE SURE THE CABLE IS SLACK.

(1) Minor adjustments compensate for normal band wear.

(2) If after making minor adjustments proper engagement and/or disengagement cannot be obtained on the bands a major adjustment is required.

OUTLINE OF INSTRUCTION

3. Hydraulic power-control units.
   - a. Hydraulic reservoir and piping.
     - (1) Model D-2 or G-2.
     - (2) Related parts.
   - b. Hydraulic pump IH (Series 28).
     - (1) Gear type.
     - (2) Positive displacement.
     - (3) Engine crankshaft.
       - (a) Driven through series of gears.
   - c. Control valve IH (Series 7).
     - (1) Single or three spool valve model.
     - (2) Major components.
       - (a) Valve body.
       - (b) Positioning spool or spools.
       - (c) Check valves.
       - (d) Main pressure relief valve.

INSTRUCTOR ACTIVITY

II.A.3.b. Have class refer to Operator's Manual, International TD20 Series "B" Crawler Tractor and Tractor Equipment Sec. 9, pp. 25 - 28 while discussing hydraulic power control units.

STUDENT ACTIVITY

II.A.3.b. Refer to text as directed by instructor and participate in instructor guided discussion.

OUTLINE OF INSTRUCTION **INSTRUCTOR ACTIVITY** **STUDENT ACTIVITY**

(3) Directs pressurized oil through connecting lines to actuate hydraulic cylinders.

d. Hydraulic cylinders.

(1) Lift cylinder.

(a) Single stage, double acting type.

(2) Tilt cylinder.

(a) Single stage, double acting type.

e. Operation.

(1) Hold position.

(a) Three or four position spools.

(b) Spool seals off the passages.

1. To cylinder lines.

(2) Raise position.

(a) Spool is positioned.

1. Allows oil to flow to cylinders from pressure side of pump through the control valve passage.

2. Passage for lowering is sealed off by the spool.

(3) Power, lower position.

(a) Operates in the same manner as the "raise" position.

1. Except the spool is positioned to direct oil to opposite end of the cylinder.

(4) Float position.

(a) Control lever moved to detent the spool.

1. Supplying pump oil to the "raise" and "lower" passages are sealed off.

f. Maintenance (Model D-2 or G-2).

(1) Checking oil level.

(a) Engine stopped.

(b) Blade or bucket resting level on the ground.

(c) Control filler and level plug.

CAUTION!! Always loosen the filler and level plug slowly in case there is still some pressure in the system.

(2) Draining the system.

OUTLINE OF INSTRUCTION	INSTRUCTOR ACTIVITY	STUDENT ACTIVITY
(a) Operate system to warm lubricant.		
(b) Drop blade below ground level and place control handle in "float" position.		
(c) Stop engine.		
(d) Drain reservoir and cylinders.		
(e) Remove the return filter element.		
1. Discard and replace.		
(f) Remove filter (outlet) and clean all parts which were removed from tank.		
(g) Thoroughly clean the interior of the reservoir before reassembly.		
(3) Filling and venting the system.		
(a) Fill the tank.		
1. Up to the level of the plug opening.		
NOTE: Refer to "Lubricant Specification and Capacities Chart" for type and quantity of lubricant required.	Have class refer to lubrication specification and capacity chart in text.	Refer to text as directed by instructor.

(b) Engine at low idle speed.

(c) Operate all the control through all positions four or five times.

(d) Recheck the lubricant level with blade resting on the ground.

(4) Inspect all hoses and connections for leaks.

(a) Correct all leaks, no matter how minor.

NOTE: When disconnecting hydraulic lines for any reason, they should be properly capped with the correct size plastic cap. Tape or clean rubber corks may be used if the plastic cap is not available. Hydraulic opening must never be plugged with rags, this practice could easily introduce dirt or lint into critical hydraulic components of the tractor.

(5) Hydraulic pump.

(a) Keep connections tight.

(b) Inspection and repair.

1. Preliminary inspection should be made as parts of the pump are removed.

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8-6

NAVAL CONSTRUCTION TRAINING CENTER
PORT HUENEME, CALIFORNIA 93043
CONSTRUCTION MECHANIC "A" SCHOOL TRAINING COURSE A-610-0022

JOB SHEET

Title: Adjustment of the International Model 260 Power Control Unit

Introduction: The purpose of this job sheet is to guide you in the practical performance of adjusting the International Model 260 Cable Control Unit.

You will adjust the International Model 260 Power Control Unit to conform to manufacturer's specifications without deviation. Your performance will be guided by job sheet and key points from the instructor's lecture/discussion.

Tools, Equipment and Materials:

A. Heavy equipment shop handtools.

B. International Model 260 Power Control Unit.

Conditions:

A. Student teams of six (6) students each are assigned to International Model 260 Power Control Unit to accomplish brake and clutch band major adjustments.

B. Each team is provided with all required tools, job sheets and manufacturer's manuals to accomplish the assigned task.

C. All background data and necessary details are covered in the classroom lecture/discussion prior to shop performance.

Procedures: (As outlined on following pages.)

608 -a

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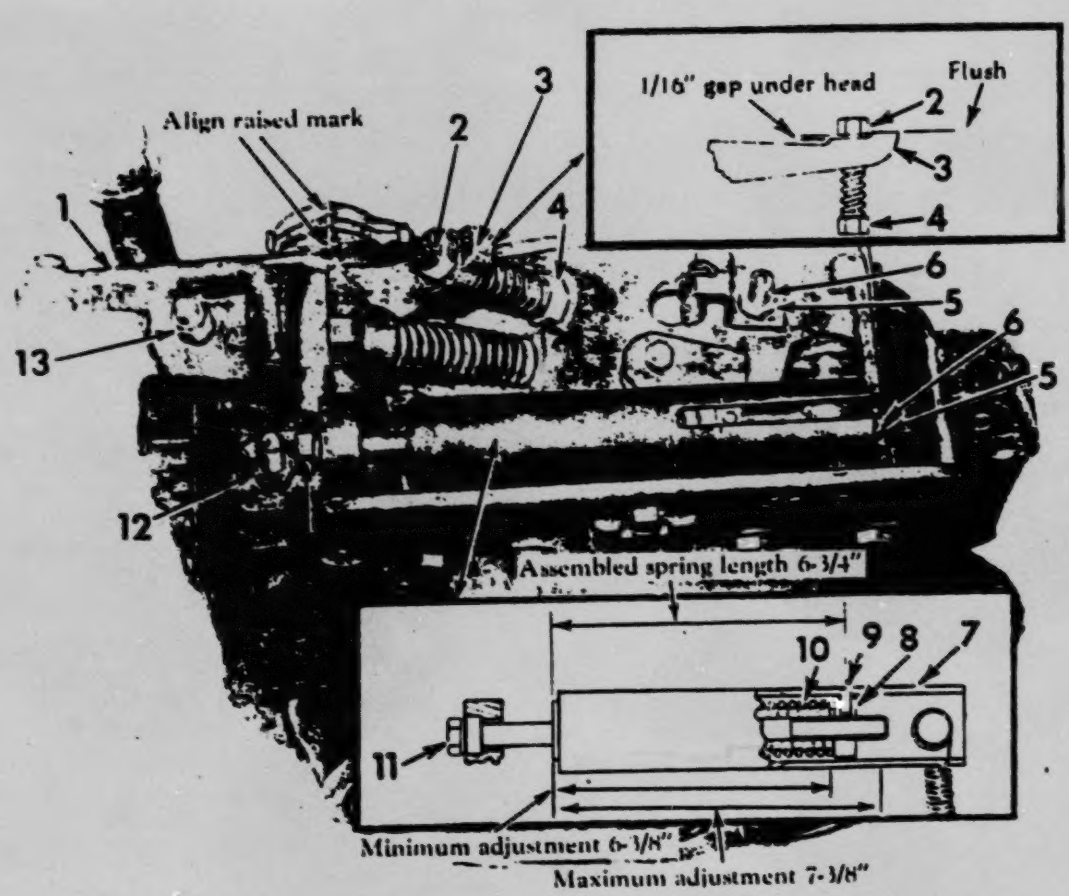
Align raised mark
1/16" gap under head
Flush
1
2
3
4
5
6
7
8
9
10
11
12
13
Assembled spring length 6-3/4"
Minimum adjustment 6-3/8"
Maximum adjustment 7-3/8"

Brake and Clutch Band Adjusting Points.

1. LEVER, clutch.
2. BOLT.
3. LEVER, brake release.
4. NUT, jam.
5. NUT, jam.
6. SCREW, set
7. HOUSING, spring.
8. BLOCK, brake spring guide end.
9. PIN, dowel.
10. SPRING, brake holding.
11. BOLT, brake holding spring.
12. NUT, brake tension rod adjusting.
13. NUT, clutch tension rod adjusting.

Leverage Adjustment.

NOTE: Never set new brake or clutch bands tight to avoid the normal adjustments required for seating. This will cause the shoe to drag and overheat the entire unit, resulting in seal failure and oil leakage.

Model 260

NOTE: The following adjustment is for one side only; if both sides need adjustment the same procedure must be repeated for the opposite side.

Continued on next page.

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CABLE CONTROL UNIT-Continued

Model 260-Continued

Brake Band Minor Adjustment (Illust. 39)

1. Place the control lever in the "HOLD" position.

2. Adjust the brake reach rod adjusting nut (A) until the brake release lever boss is flush with the bottom of the bolt (B). This provides a 1/16 inch clearance between the bolt head and the brake release lever.

> **NOTE:** Do not adjust bolt (B) to regain the necessary 1/16 inch clearance under the bolt heads. This is done only by adjusting with nut (A).

3. Adjust the clutch band as described under "Clutch Band Minor Adjustment" which follows. This is necessary after a brake band adjustment.

Clutch Band Minor Adjustment

Whenever the hand lever free travel increases two inches over the normal specified free travel or whenever the brake band has been adjusted, the clutch band must be adjusted.

Measure the free travel as follows:

1. Place the hand lever in the "HOLD" position.

2. Pull the lever, using one finger, from the "HOLD" position to the "RAISE" position (toward the operator) and measure this distance. This distance is the free travel.

The cable control unit linkage (Illust. 38) can be adjusted to provide either a three or four inch (reduced lever effort) hand lever free travel.

a. THREE INCH FREE TRAVEL: Connect the control link in hole (E, Illust. 38) and adjust nut (C, Illust. 39) to obtain a three inch free travel.

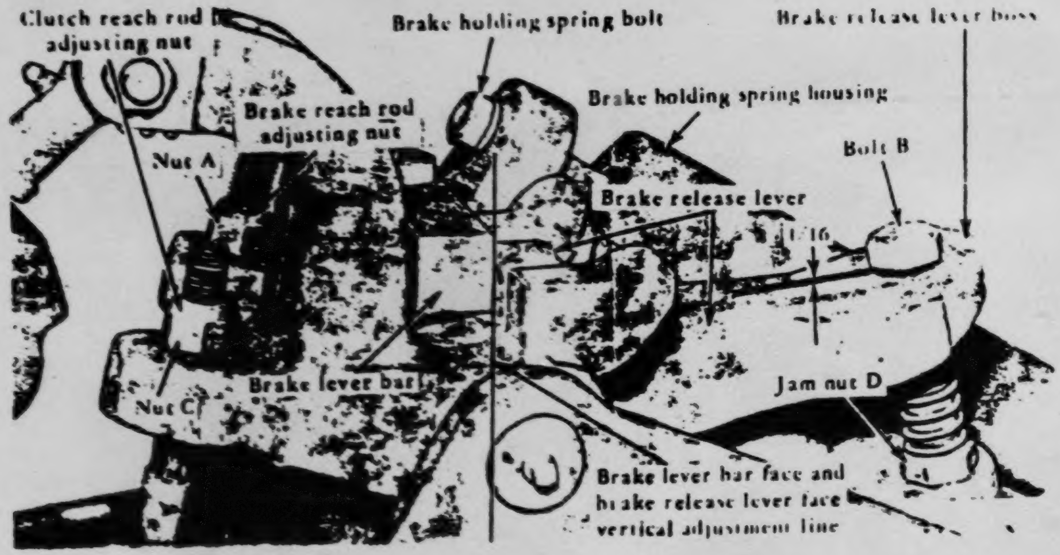
b. FOUR INCH FREE TRAVEL: Connect the control link in hole (F, Illust. 38) and adjust nut (C, Illust. 39) to obtain a four inch free travel for reduced lever effort.

Brake and Clutch Band Major Adjustment (Illust. 39)

This procedure must be followed in sequence.

1. Disconnect the adjustable control link from the bell crank (Illust. 38).

2. Loosen the jam nut (D) and bolt (B) to permit unrestricted movement of the brake release lever.


Clutch reach rod adjusting nut
Brake holding spring bolt
Brake release lever boss
Brake holding spring housing
Brake reach rod adjusting nut
Nut A
Bolt B
Brake release lever
1/16
Brake lever bar
Nut C
Jam nut D
Brake lever bar face and brake release lever face vertical adjustment line

Band Adjustments.

3. Loosen the clutch reach rod adjusting nut (C) until the reach rod can be lifted with the fingers and indicates a 1/4 inch gap under the adjusting nut (C).

4. Back off the brake holding spring bolt until the dowel pin is 7-3/8 inches from the end of the spring housing (Illust. 41).

5. Loosen the band hold-off spring set screw jam nuts and back the set screws out several turns.

6. Adjust the brake reach rod nut (A) until the faces of the brake release lever and brake lever bar are vertical. Be sure that clearance is maintained under the head of the bolt (B) and the clutch reach rod is loose (refer to Step 3).

7. Tighten the brake holding spring bolt until the dowel pin is approximately 6-3/4 inches from the end of the brake holding spring housing (Illust. 41). After making this adjustment, it may be necessary to repeat the adjustment outlined in Step 6.

8. Adjust the bolt (B) so the bottom of the bolt head is flush with the boss on the brake release lever (Illust. 42). This provides a 1/16 inch clearance between the bolt head and the brake release lever. Tighten the jam nut (D) at the lower end of the bolt (B).

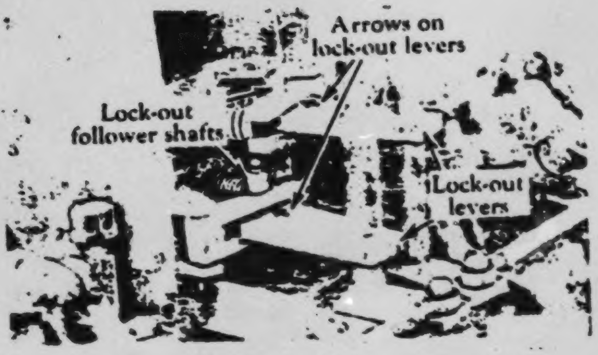
9. Using an Allen wrench, turn in the band hold-off spring set screws until the screws bottom solidly against the shoes. Back off one to two turns on each screw and lock in place with the jam nut.

10. Position the tiller post so the arrow on the lock-out lever aligns with the center of the lock-out follower shaft (Illust. 40). Loosen the jam nut on the adjustable control link (Illust. 38) and lengthen or shorten the link until the rod end bearing bore aligns with the hole in the bell crank. Tighten the control link jam nut. Secure the control link to the bell crank using the cap screw.

11. Adjust the clutch as outlined under "Clutch Band Minor Adjustment" on page 38 in this section.

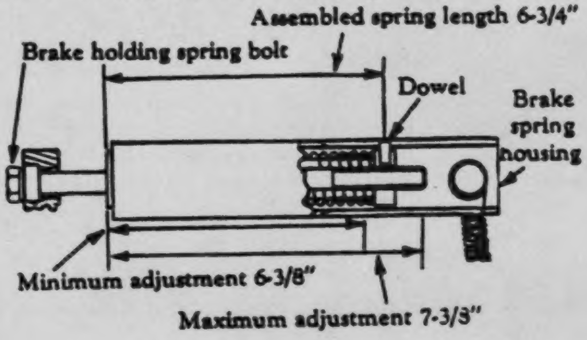
12. If, after placing the unit into operation, it is found that the brake slips or does not hold the load and all adjustments are correct, tighten the brake holding spring bolt (turn clockwise). When tightening the bolt, move the dowel in the brake spring housing only 1/16 inch at a time and recheck brake operation.

NOTE: The dowel must never be less than 6-3/8 inches or more than 7-3/8 inches from the end of the spring housing.



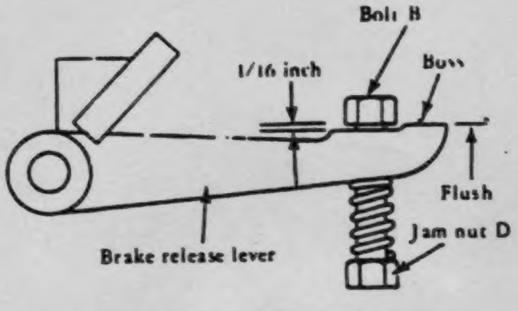
Tiller Adjustment.

13. If new clutch or brake drum shoes have been installed, the shoes must be allowed to seat under actual operating conditions. Check the hand lever free travel and the clearance under the bolt (B, Illust. 42) at frequent intervals for the first 100 hours of operation. If either or both of these dimensions have changed, perform either the "Brake Band Minor Adjustment" and/or "Clutch Band Minor Adjustment" on page 3 of 4 this job sheet.


Assembled spring length 6-3/4"
Brake holding spring bolt
Dowel
Brake spring housing
Minimum adjustment 6-3/8"
Maximum adjustment 7-3/8"

Brake Holding Spring Housing.

NOTE: Never set new brake or clutch bands tight to avoid the normal adjustments required for seating. This will cause the shoe to drag and overheat the entire unit, resulting in seal failure and oil leakage.



Brake Release Lever Travel Adjustment.

NAVAL CONSTRUCTION TRAINING CENTER
PORT HUENEME, CALIFORNIA 93043
CONSTRUCTION MECHANIC "A" SCHOOL TRAINING COURSE A-610-0022

JOB SHEET

Title: Oxy-Mapp Gas Heating and Cutting

Introduction: Selection of the correct cutting tip, gas pressure and preheating flame to bring steel up to a kindling temperature. Cut straight line cuts.

Tools, Equipment and Materials.

A. Tools:

  1. Hand tools.
    a. Chipping hammer.
    b. Wire brush.
    c. Pliers, 8 inch.

B. Equipment:

  1. Oxy-Mapp cutting unit with all accessories.
  2. Safety equipment.
    a. Goggles.
    b. Gloves.
    c. 15 lb. CO_2 extinguisher.

C. Materials:

  1. Scrap steel.
  2. Soap stone.

Procedures:

A. Secure cylinders.

  1. Strap or chain cylinders upright.
    a. Have cylinders setting directly on deck.

B. Clean valves.

1. Crack cylinders slightly to blow out dust.

    a. Have valves pointing away from person when cleaning.

C. Attach regulators.

1. Hold regulators in one hand, screw on with the other and tighten snugly.

    a. The mapp regulator has left hand threads and the oxygen regulator has right hand threads.

D. Hook up hoses to regulator.

1. Hoses with grooved nuts are attached to mapp regulator.

    a. Mapp hoses have left hand threads and oxygen have right hand threads.

E. Attach hoses to torch butt.

1. Attach mapp hose to left hand threads and oxygen to right hand threads of torch butt.

    a. Avoid getting oil or grease on connections.

F. Attach cutting attachment to torch butt.

1. Screw on cutting attachment hand tight.

G. Select the correct cutting tip.

1. Determined by plate thickness.
   Note: Use chart on page 5 of this Job Sheet to determine correct tip size.

    a. Cutting attachment has right hand thread.

H. Attach cutting tip.

1. Remove nut on cutting attachment head, insert tip and replace nut.

    a. Blow out any dust on seat of cutting head.

I. Close regulators.

1. Turn out screws on both regulators (counterclockwise).

    a. Turn until loose.

J. Open oxygen tank.

  1. Open completely.

    a. Do not tighten valve at open.

K. Open Mapp tank.

  1. Open only one full turn.

L. Set regulators at cutting pressure.

  1. Determined by tip size.
  Note: Use chart on page 5 of this Job Sheet to determine correct pressure.

M. Blow out air from Mapp hose.

  1. Open Mapp needle valve and permit a small amount of Mapp to escape and then close valve.

    a. Permit gas to escape in an unconfined area.

N. Blow out air from oxygen hose.

  1. Open oxygen needle valve and permit a small amount of oxygen to escape and then close valve.

    a. Direct escaping oxygen away from person.

O. Adjust preheating flame to neutral.

  1. Turn on Mapp needle valve.

    a. Check surroundings for combustible materials.

    b. Never cut on a tank or container until a safety check has been made.

  2. Light torch with spark lighter.

  3. Turn on oxygen valve of torch completely.

  4. Turn on oxygen valve on cutting attachment until neutral flame is formed on preheating holes.

P. Heat metal to kindling temperature.

  1. Bring metal up to a cherry red.

    a. Cherry red in daylight.

Q. Make a straight cut.

  1. Hold preheating flames approximately 1/16" above metal.

R. Safety in cutting.

  1. Never use Mapp welding or cutting tips with acetylene.

Questions:

A. When the metal is preheated to kindling temperature, what color is it?

ANS: Cherry red.

B. What determines the size of tip to be selected?

ANS: The thickness of metal to be cut.

C. What determines the oxygen and Mapp pressure to be used?

ANS: The size of tip selected.

D. Is the preheating flame adjusted to carbonizing neutral or oxidizing?

ANS: Neutral.

E. How close should the preheating flame be held to the base metal on a straight line?

ANS: 1/16".

References:

A. Steelworker 3 & 2, NAVPERS 10653-E, pages 187-200.

B. Naval Construction Force Safety Manual COMCBPAC/COMCBLANT inst. 5100.1.

C. Welding Encyclopedia, 16th edition, pages F-15 to F-38.

CUTTING TIP SELECTION CHART

PLATE THICKNESS	TIP SIZE NO.	OXYGEN PRESSURE PSI	MAPP PRESSURE PSI
3/16"	72	30-40	2-6
1/4"	68	35-45	2-6
3/8"	65	35-45	2-8
1/2"	60	40-50	2-8
3/4"	56	40-50	2-10
1"	56	40-50	2-10
1 1/4"	54	40-60	2-10
1 1/2"	54	40-60	2-10
2"	52	40-60	2-10

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Heavy chasis

NAVAL CONSTRUCTION TRAINING CENTER
PORT HUENEME, CA. 93043

CONSTRUCTION MECHANIC CLASS "A" COURSE NUMBER A-610-0022

Title: Servicing the D4D Caterpillar Crawler Tractor Power Train, hereafter referred to as the D4D.

Introduction:

The purpose of this Job Sheet is to guide you in the practical performance of removing, disassembly, inspecting, repairing, reassembly, and adjusting the Power Train Components of the D4D. The components to be covered are the master clutch, the transmission, the steering clutches, the bevel gear, the track frame, and the final drive assemblies.

You will select and safely use all tools and equipment required to accomplish all procedures on this Job Sheet.

All safety precautions that are applicable to you, your team mates and the equipment must be observed at all times.

Every procedure must be done in accordance with this Job Sheet and manufacturers specifications without error.

Tools and Equipment:

A. Caterpillar D4D Crawler Tractors

B. Caterpillar Special Tools

C. Heavy Equipment Shop Handtools

D. Hoist, Chain

E. Tressle, Hoist (A-Frame)

F. Torque Wrench

G. Task Job Sheet

H. Manufacturer's Service Manual

Conditions:

A. Student teams of four (4) men each are assigned to a D4D tractor to accomplish the tasks of disassembly, inspection, repair, reassembly, and adjustment of the power train components.

Procedure:

A. As outlined on the attached pages of the Equipment Work Order (EWO) and continuation sheets.

1. Master Clutch
2. Transmission
3. Steering Clutches
4. Power Train Reassembly and Adjustment
5. Track Roller Frame
6. Final Drive
7. Track Frame Reassembly and Adjustment
8. Maintenance/operator Services

EQUIPMENT WORK ORDER
AVFAC 6-11200/41 (REV 5-69)

THIS "EWO" IS TO BE USED FOR REPAIR OF ALL EQUIPMENT ASSIGNED:

NAVAL CONSTRUCTION FORCES
SPECIAL OPERATIONAL UNITS
NAVAL CONSTRUCTION SCHOOLS

1. U S N. NO 4 8 2 2 2 2 1

E & O NO: 4 "A" JS 4.1.2.1

3. JOB ORDER NO. Page 3 of 4

4. PROJECT Construction Equipment Power Train

5. UNIT ID CODE 0 [illegible] 2 A

6. ZIP CODE 9 3 0 4 3

7. EQUIP. CODE 4 8 1 0

UNIT IDENTIFICATION .S. Naval Construction Training Center

9. MAKE Caterpillar

10. MODEL D[illegible]

11. YR OF MFG. 6 5

12. MILES

13. HOURS

8. EQUIPMENT DESCRIPTION ractor,Crawler DED W/O Attachments

Use adjacent space for reporting man-hours of inspection time, when estimates are prepared for a customer prior to authorization to proceed with repairs.

15. DATE IN / OUT

16. INSPECTION MAN-HOURS INSPECTOR / MECHANIC

17. TOTAL HOURS Add to Block (37)

18. TYPE MAINTENANCE REPAIR Check appropriate box

PM SERVICE DUE A(1)	B(2)	C(3)	INTERIM (4)	OVERHAUL (5)
		XXXX		

19. LAST PM SERVICES (Miles or Hours) Indicate "M" for Miles: "H" for Hours.

"A"	"B"	"C"

MATERIAL RECORD

20. FSN MFG. PART	21. DESCRIPTION	22. QTY.	23. COST	24. WORK CTR.	25. LCC	26. MAN-HOURS EST.	ACT.	27. WORK DESCRIPTION	27A. P OR S	28. MECH. INIT.
				A				Remove Master Clutch,Disassemble & Inspect For Worn Or Defective Parts. Renew As Requir 1. Reassemble		
				B				Remove Transmission & Transmission Speed Selector Housing		
				C				Remove Steering Clutches & Bevel Gear Assembly. Disassemble & Inspect For Worn Or Defective Parts. Renew As Required. Reassemble		
				D				Install Master Clutch,Transmission & Steering Clutch Assembly		

Enter portion of Col. 23 that is OPERATING COST → 29. $

30. $ ← Enter portion of Col. 23 that is MAINTENANCE COST

35 FUNCTION GROUP (Check appropriate blocks) → 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24

31	TIME	DATE	32. JULIAN DATE
COMPLETED	31A		
PARTS AVAILABLE			DFM
STOP FOR PARTS			DFS
PARTS AVAILABLE			DFM
STOP FOR PARTS			DFS
INSPECTION START	31B		DFM
EQUIPMENT AVAILABLE	31C 619	31D JULIAN DATE	32A JULIAN DATE

33. TOTAL DOWN FOR MAINT. TIME

34. TOTAL DOWN FOR SUPPLY TIME

36. SIGNATURES

INSPECTOR		DATE
CM2 Benton		24 May
MAINTENANCE SUPERVISOR		DATE
CMC Baker		24 May
SECTION SUPERVISOR	INITIAL	DATE
CM1 May		25 May

37. WHOLE HOURS ← TOTAL ACTUAL LABOR HOURS

OPERATING COST 38. DOLLARS CENTS

MAINTENANCE COST 39. DOLLARS CENTS

40. TOTAL COST $

620

SHOP REPAIR ORDER
(Continuation Sheet)

PAGE 4 OF 4

(1) SRO NUMBER CM "A" JS 4.1.2.1

(2) JOB ORDER NO Construction Equipment Power Train

48=22221

MATERIAL RECORD									
QTY	(25) DESCRIPTION	(26) MFG. PART NO.	(27) AMOUNT	(28) WORK CTR.	(29) LCC	(30) MAN-HRS. STD	ACT.	(31) WORK DESCRIPTION	(32)
								Adjust To Manufacturer, Specifications	
				E				Remove Track Roller Frame Assembly, Inspect For Worn Or Defective Parts. Renew As Required	
				F				Remove Final Drive Assembly, Inspect For Worn Or Defective Parts. Renew As Required.	
				G				Reassemble And Install Final Drive And Track Roller Frame Assembly.	
								Adjust To Manufacturers Specifications	
				H				Conduct Pre-Start Check	
			$	TOTAL LABOR HRS.					

NOTE Add the Total Amount of Column (27) to Item (34) on the original SRO. Add Total Hours of Col. 30 to Item [illegible] on the original SRO.

Fluid Power 377

8-6

CHAPTER 1

HISTORY AND DEVELOPMENT

Fluid Power, NavPers 16193-B, presents many of the fundamental concepts in the fields of hydraulics and pneumatics. This manual is intended as a basic reference for all personnel of the Navy whose duties and responsibilities require them to have a knowledge of the fundamentals of fluid power. Consequently, emphasis is placed primarily on the theory of operation of typical fluid power systems and components that have applications in naval equipments. Many applications of fluid power are presented in this manual to illustrate the functions and operation of different systems and components. However, these are only representative of the many applications of fluid power in naval equipments. Individual rate training manuals should be consulted for information concerning the application of fluid power to specific equipments for which each rating is responsible.

In addition, the examples of systems and components presented in this manual are used to illustrate the functions and operation of certain types. Since there are many different manufacturers of fluid power systems and components, each type presented may represent several different models or designs. Therefore, this manual is not intended for use in the maintenance and repair of specific equipments. Applicable technical publications and technical instructions should be used for this purpose. These terms, applicable technical publications and applicable technical instructions, are frequently referred to in this manual. They include such documents as the following.

1. Certain chapters of the Naval Ships Technical Manual.
2. Operation, maintenance, repair, overhaul, and parts manuals, which are provided by the manufacturer of the component, system, and/or equipment. These manuals are usually approved by the appropriate command— Naval Ships Systems Command, Naval Air Systems Command, etc.
3. Maintenance Requirements Cards (MRC's).
4. Military Standards and Specifications.
5. Instructions and Notices.

FLUID POWER

Fluid power is a relatively new term which was established to include the generation, control, and application of smooth, effective power of pumped or compressed fluids (either liquids or gases) when this power is used to provide force and motion to mechanisms. This force and motion may be in the form of pushing, pulling, rotating, regulating, or driving. Fluid power includes hydraulics, which involves liquids, and pneumatics, which involves gases. Liquids and gases are similar in many respects and therefore are described as fluids in most sections of this manual. The differences are pointed out in the appropriate areas. In these areas they are treated separately as liquids and gases, or as in the following sections, as hydraulics and pneumatics.

HYDRAULICS

The word hydraulics is a derivative of the Greek words hydro (meaning water) and aulis (meaning tube or pipe). Originally, the science of hydraulics covered the physical behavior of water at rest and in motion. This dates back several thousand years ago when water wheels, dams, and sluice gates were first used to control the flow of water for domestic use and irrigation. Use has broadened its meaning to include the physical behavior of all liquids. This includes that area of hydraulics in which confined liquids are used under controlled pressure to do

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work. This area of hydraulics, sometimes referred to as "power hydraulics," is discussed in this manual.

Hydraulics can be defined as that engineering science which pertains to liquid pressure and flow. This science includes, for example, the manner in which liquids act in tanks and pipes, dealing with their properties and with ways of utilizing these properties. It includes the laws of floating bodies and the behavior of liquids on submerged surfaces. It treats the flow of liquids under various conditions, and ways of directing this flow to useful ends, as well as many other related subjects.

There are several other terms which are sometimes used to more precisely describe the behavior of liquids at rest and in motion. These terms are generally considered separate branches of science and include: hydrostatics, that branch of science pertaining to the energy of liquids at rest; hydrodynamics, the branch of science pertaining to the energy of liquid flow and pressure; and hydrokinetics, which pertains to motions of liquids or the forces which produce or affect such motions.

Development

Although the modern development of hydraulics is of comparatively recent date, the ancients were familiar with many hydraulic principles and their applications. The Egyptians and the ancient peoples of Persia, India, and China conveyed water along channels for irrigation and domestic purposes, using dams and sluice gates to control the flow. The ancient Cretans had an elaborate plumbing system. Archimedes studied the laws of floating and submerged bodies. The Romans constructed aqueducts to carry water to their cities.

After the breakup of the ancient world, there were few new developments for many centuries. Then, over a comparatively short period, beginning not more than three or four hundred years ago, the physical sciences began to flourish, thanks to the discovery of principles basic to all of them, and to the invention of many new mechanical devices. Thus, the fundamental law underlying the entire science of hydraulics was discovered by Pascal in the 17th century.

Pascal's theorem was as follows: "If a vessel full of water, and closed on all sides, has two openings, the one a hundred times as large as the other, and if each is supplied with a piston that 'fits it exactly,' then a man pushing the small piston will exert a force that will equilibrate (balance) that of one hundred men pushing the large piston and will overcome that of ninety-nine men." (This is the basic principle of hydraulics and is covered in detail in chapter 2.)

For Pascal's law to be made effective for practical applications, it was necessary to have a piston that "fit exactly." It was not until the latter part of the 18th century that methods were found to make these snugly fitted parts required in hydraulic systems. This was accomplished by the invention of machines which were used to cut and shape the necessary closely fitted parts and, particularly, by the development of gaskets and packings. Since that time, such components as valves, pumps, actuating cylinders, and motors have been developed and refined to make hydraulics one of the leading methods of transmitting power.

Application

Today, hydraulic power is used to operate many different tools and mechanisms. In a garage, a mechanic raises the end of an automobile with a hydraulic jack. Dentists and barbers use hydraulic power to lift and position their chairs to a convenient working height by a few strokes of a control lever. Hydraulic doorstops keep heavy doors from slamming. Hydraulic brakes have been standard equipment on automobiles for approximately 35 years. Most automobiles are equipped with automatic transmissions that are hydraulically operated. Power steering is another application of hydraulic power. Construction men depend upon hydraulic power for the operation of various components of their equipment. For example, the blade of a bulldozer is normally operated by hydraulic power.

During the period preceding World War II, the Navy began to apply hydraulics to naval mechanisms extensively. Since then, naval applications have increased to the point where many ingenious hydraulic devices are used in the solution of problems of gunnery, aeronautics, and navigation. Aboard ship, hydraulic power is utilized to operate such equipment as anchor windlasses, power cranes, steering gear, remote control devices, power drives for elevating and training guns and rocket launchers. Some elevators on aircraft carriers utilize hydraulic power to transfer aircraft from the hanger deck to the flight deck and vice versa.

Most naval aircraft contain a network of hydraulic lines and components. Hydraulic power is used to operate such units as wheel brakes, landing flaps, antennas, speed brakes, control surfaces, and the retraction and extension of the landing gear. Many types of guided missiles contain hydraulic systems for the operation of flight control devices.

PNEUMATICS

The word pneumatics is a derivative of the Greek word pneuma, which means air, wind, or breath. It can be defined as that branch of engineering science which pertains to gaseous pressure and flow. As used in this manual, pneumatics is that portion of fluid power in which compressed air, or other gas, is used to transmit and control power to actuating mechanisms.

Development

There is no record of man's first use of air to do work. Probably the first were fans used to separate the chaff from grain and the use of sails to move ships. One of the first pneumatic devices was the blow gun used by primitive man. In the latter part of the 18th century, heated air was used to carry the first balloon aloft. The heated air was allowed to expand in the balloon, and therefore it became lighter than the surrounding air and caused the balloon to rise.

Every age of man has witnessed the development of devices to utilize air to do work. However, it can be seen that man used air for work long before he understood it.

Many of the principles of hydraulics apply to pneumatics. For example, Pascal's law applies to gases as well as liquids. Also, like hydraulics, the development of pneumatics depended upon closely fitted parts and the development of gaskets and packings. Since the invention of the air compressor, pneumatics has become a very reliable source for the transmission of power.

Application

The fluid medium for pneumatic systems is usually compressed air or nitrogen. Compressed air has been used for many years and is still the most widely used fluid medium. As discussed in chapter 3, nitrogen has many of the qualities desired in the fluid medium for pneumatic systems and is, therefore, recommended for use in some systems.

Probably one of the greatest uses of pneumatic power is in the operation of the various types of pneumatic tools. Pneumatic drills, screwdrivers, and nut setters are operated by air motors. Riveting guns and chipping hammers are usually operated by air pressure. Compression tools such as rivet squeezers and punches are operated with pneumatic power. Trains, buses, and large trucks are normally equipped with air brakes.

Most models of aircraft contain pneumatic systems as an emergency means of operating those units that are normally operated hydraulically. Guided missiles utilize compressed gas as a power source for electrical generators and hydraulic pumps. In some missiles, pneumatic power is utilized to operate flight control devices.

Pneumatics and hydraulics are combined for some applications. This combination is sometimes referred to as hydropneumatics. An example of this combination is the lift used in garages and service stations. Air pressure is applied to the surface of hydraulic fluid in a reservoir. The air pressure forces the hydraulic fluid to raise the lift. The accumulator, described in chapter 7, is another example of this combination.

ADVANTAGES OF FLUID POWER

The extensive use of hydraulics and pneumatics to transmit power is due to the fact that properly constructed fluid power systems possess a number of favorable characteristics. They eliminate the need for complicated systems of gears, cams, and levers. Motion can be transmitted without the slack inherent in the use of solid machine parts. The fluids used are not subject to breakage as are mechanical parts, and the mechanisms are not subjected to great wear.

The different parts of a fluid power system can be conveniently located at widely separated points, and the forces generated are rapidly transmitted over considerable distances with small loss. These forces can be conveyed up and down or around corners with small loss in efficiency and no complicated mechanisms. Very large forces can be controlled by much smaller ones, and can be transmitted through comparatively small lines and orifices.

If the system is well adapted to the work it is required to perform, and if it is not misused, it can provide smooth, flexible, uniform action without vibration, and is unaffected by variation of load. In case of an overload, an automatic release of pressure can be guaranteed, so that the system is protected against breakdown or strain. Fluid power systems can provide widely variable motions in both rotary and straight-line transmission of power. Need for control by hand can be minimized. In addition, fluid power systems are economical to operate.

The question may arise as to why hydraulics is used in some applications and pneumatics in others. Many factors are considered by the user and/or the manufacturer when determining which power source to use in a specific application. There are no hard and fast rules to follow; however, past experience has provided some sound ideas that are usually considered when making such decisions. If the application requires speed, a medium amount of pressure, and only fairly accurate control, a pneumatic system may be used. If the application requires only a medium amount of pressure and a more accurate control, a combination of hydraulics and pneumatics may be used. If the application requires a great amount of pressure and/or extremely accurate control, a hydraulic system should be used.

SPECIAL PROBLEMS

The extreme flexibility of fluid power elements gives rise to a number of problems. Since fluids have no shape of their own, they must be positively confined throughout the entire system. Special consideration must be given to the structural organization and the relation of the parts of a fluid power system. Strong pipes and containers must be provided. Leaks must be prevented. This problem is acute with the high pressure obtained in many fluid power installations.

The pressures required in fluid power systems must be controlled and likewise the movement of the fluid within the lines and components. This movement causes friction, within the fluid itself and against the containing surfaces, which if excessive, can lead to serious losses in efficiency. Foreign matter must not be allowed to accumulate in the system, where it will clog small passages or score closely fitted parts. Chemical action may cause corrosion. Above all, it is necessary to know how a fluid power system and its components operate both in terms of the general principles common to all physical mechamisms and the peculiarities of the particular arrangement at hand.

CHAPTER 2

PHYSICS OF FLUIDS

The operation of any fluid power system, regardless of its complexity, can be satisfactorily explained as an application of physics. Physics is that branch of science which deals with matter and energy. It is devoted to finding and defining problems, as well as searching for their solutions. It not only teaches a person to be curious about the physical world, but also provides a means of satisfying that curiosity. The science of physics is divided into five major areas—mechanics, heat, acoustics (sound), optics (light), and electricity. Further divisions may include such areas as magnetism, radiation, atomic structure, and nuclear phenomena. For the most part, fluids are included in the area of mechanics. In fact, many physics textbooks refer to fluids as the mechanics of liquids and the mechanics of gases. It should be pointed out, however, that the study of fluids is not limited to the area of mechanics. For example, heat (changes in temperature) has a definite effect on the physical characteristics of fluids.

In order to operate, service, and maintain fluid power systems, an understanding of the basic principles of fluids at rest and in motion is essential. There can be no question that the mechanic or technician who possesses this understanding is better equipped to meet the demands placed upon him in his everyday tasks.

In the study of the principles of hydraulics and pneumatics, it soon becomes obvious that specific words and terms have specific meanings which must be mastered from the start. Without an understanding of the exact meaning of the term, there can be no real understanding of the principles involved in the use of the term. Once the term is correctly understood, however, many principles may be discussed briefly to illustrate or to emphasize the particular aspects of interest. The terms pertaining to the principles of hydraulics and pneumatics are discussed in this chapter. This discussion covers the physical properties and characteristics of fluids, including the similarities and differences in the characteristics of liquids and gases. Also included are the outside factors which influence the characteristics of fluids at rest and in motion, and the laws which govern the action of fluids under specific and fixed conditions.

STATES OF MATTER

The material substance which makes up the universe is known as matter. Matter is defined as any substance which occupies space and has weight. Examples covered by this definition are iron, water, and air. Each of these occupies space and has weight. In contrast, heat, light, and electricity are not included because they do not take up space and cannot be weighed. They are forms of energy which are described later in this chapter. Although the three examples of matter—iron, water, and air—are all forms of matter, each one has distinguishing characteristics. They represent the three states of matter—solids, liquids, and gases. Solids have a definite volume and a definite shape; liquids have a definite volume, but take the shape of the containing vessel; gases have neither a definite volume nor a definite shape. Gases not only take the shape of the containing vessel, but they expand and fill the vessel, regardless of the volume of the vessel.

Matter can change from one state to another. Water is a good example. At high temperatures it is in the gaseous state known as steam. At moderate temperatures it is a liquid, and at low temperatures it becomes ice, which is definitely a solid state. In this example, the temperature is the dominant factor in determining the state that the substance assumes. Pressure is another important factor that will effect changes in the state of matter. At pressures lower than atmospheric, water will boil and thus change into steam at temperatures lower than 212° Fahrenheit (F). Pressure is also a critical factor in changing some gases to liquids or solids. Normally, when pressure and chilling are both applied to a gas, it assumes a liquid state. Liquid air, which is a mixture of oxygen and nitrogen, is produced in this manner.

In the study of fluid power, we are concerned primarily with the properties and characteristics of liquids and gases. However, it should be kept in mind that the properties of solids also affect the characteristics of liquids and gases. The lines and components, which are solids, enclose and control the liquid or gas in the respective systems.

FLUIDS

The word fluid is derived from the Latin word "fluidus" meaning to flow. A fluid is defined as a substance which tends to flow or to conform to the outline of its container. Since this definition applies to both liquids and gases, they are commonly referred to as fluids. However, liquids and gases are distinct states of matter and, therefore, differ in some respects. The characteristics of liquids and gases may be grouped under similarities and differences.

Similar characteristics are listed as follows:

1. Each has no definite shape but conforms to the shape of its container.
2. Both readily transmit pressures.

Characteristics which differ are listed as follows:

1. Gases fill their containers completely, while liquids may not.
2. Gases are lighter than equal volumes of liquids.
3. Gases are highly compressible, while liquids are only slightly so.

The following discussion concerns the physical properties and characteristics of liquids and gases. In this discussion, the two substances are treated as fluids; however, the differences in their properties and characteristics are described in the appropriate areas. Also included are some of the outside factors which affect fluids in different situations.

DENSITY AND SPECIFIC GRAVITY

The density of a substance is its weight per unit volume. The unit volume selected for use in the English system of measurement is 1 cubic foot. In the metric system it is the cubic centimeter. Therefore, density is expressed in pounds per cubic foot or in grams per cubic centimeter.

To find the density of a substance, its weight and volume must be known. Its weight is then divided by its volume to find the weight per unit volume.

EXAMPLE: The liquid which fills a certain container weighs 1,497.6 pounds. The container is 4 feet long, 3 feet wide, and 2 feet deep. Its volume is 24 cubic feet (4 ft x 3 ft x 2 ft). If 24 cubic feet of liquid weighs 1,497.6 pounds, then 1 cubic foot weighs $\frac{1{,}497.6}{24}$ or 62.4 pounds. Therefore, the density of the liquid is 62.4 pounds per cubic foot.

This is the density of water at 4° Celsius (C) and is usually used as the standard for comparing densities of other substances. (Celsius, formerly known as centigrade, and other temperature scales are described later in this chapter.) Using the metric system of measurement, the density of water is 1 gram per cubic centimeter. The standard temperature of 4° C is used when measuring the density of liquids and solids. Changes in temperature will not change the weight of a substance, but will change the volume of the substance by expansion or contraction, thus changing the weight per unit volume.

The procedure for finding density applies to all substances; however, it is necessary to take pressure into consideration when computing the density of gases. Also, temperature is more critical when measuring the density of gases than it is for other substances. The density of a gas increases in direct proportion to the pressure exerted on it. Standard conditions for the measurement of the densities of gases have been established at 0° C for temperature and 76 centimeters of mercury. (This is the average pressure of the atmosphere at sea level, which is approximately 14.7 pounds per square inch.) The density of all gases is computed under these conditions.

It is often necessary to compare the density of one substance with that of another. For this purpose a standard is needed. Water is the standard that physicists have chosen with which to compare the densities of all solids and liquids. Air is most commonly used as the standard for gases; however, hydrogen is used in some instances. In physics, the word specific implies a ratio. Weight is the measure of the earth's attraction for a body. The earth's attraction for a body is called gravity. Thus, the ratio of the weight of a unit volume of some standard substance, measured under the standard pressure and temperature conditions, is called specific gravity. The terms specific weight and specific density are sometimes used to express this ratio.

The following formulas are used to find the specific gravity (sp gr) of solids and liquids.

$$\text{sp gr} = \frac{\text{Weight of the substance}}{\text{Weight of an equal volume of water}}$$

or,

$$\text{sp gr} = \frac{\text{Density of the substance}}{\text{Density of water}}$$

The same formulas are used to find the specific gravity of gases by substituting air or hydrogen for water.

The specific gravity of water is 1 $\left(\frac{62.4}{62.4}\right)$. If a cubic foot of a certain liquid weighs 68.64, then its specific gravity is 1.1 $\left(\frac{68.64}{62.4}\right)$. Thus, the specific gravity of the liquid is the ratio of its density to the density of water. If the specific gravity of a liquid or solid is known, the density of the liquid or solid may be obtained by multiplying its specific gravity by the density of water. For example, if a certain hydraulic liquid has a specific gravity of 0.8, 1 cubic foot of the liquid weighs 0.8 times as much as a cubic foot of water—62.4 times 0.8 or 49.92 pounds. In the metric system, 1 cubic centimeter of a substance with a specific gravity of 0.8 weighs 1 times 0.8 or 0.8 grams. (Note that in the metric system the specific gravity of a liquid or solid has the same numerical value as its density, because water weighs 1 gram per cubic centimeter. Since air weighs 1.293 grams per liter, the specific gravity of gases does not equal the metric densities.)

Specific gravity and density are independent of the size of the example under consideration and depend only upon the substance of which it is made. See table 2-1 for typical values of specific gravity for various substances.

A device called a hydrometer is used for measuring specific gravity of liquids. This device consists of a tubular shaped glass float which is contained within a larger glass tube. (See fig. 2-1.) The larger glass tube provides the container for the liquid. There is a small opening at one end of the container and the other end is fitted with a rubber suction bulb. This provides a means of filling or partially filling the container with the liquid. There must be enough liquid in the container to raise the float and prevent it from touching the bottom. The float is weighted and has a vertically graduated scale. To determine the specific gravity, the scale is read at the surface of the liquid in which the float is immersed. An indication of 1000 is read when the float is immersed in pure water. When immersed in a liquid of greater density the float rises, indicating a greater specific gravity. For liquids of lesser density than water, the float sinks, indicating a lower specific gravity.

An example of the use of the hydrometer is to determine the specific gravity of the electrolyte (battery liquid) in an automobile battery. When the battery is discharged, the calibrated float immersed in the electrolyte will indicate 1150. The indication of a fully charged battery is 1270.

BUOYANCY

A body submerged in a liquid or a gas weighs less than when weighed in free space. This is due to the upward force that the fluid exerts on the submerged body. An object will float if this upward force of the fluid is greater than the weight of the object. Objects denser than the fluid, even though they sink readily, appear to lose a part of their weight when submerged. An individual can

Table 2-1.—Typical values of specific gravity

Solids	sp gr	Liquids (Room temperatures)	sp gr	Gases (Air standard at 0°C and 76.0 centimeters of mercury)	sp gr
Aluminum	2.7	Alcohol, ethyl	0.789	Air	1.000
Bronze	8.8	Gasoline	0.68- 0.72	Hydrogen	0.0695
Copper	8.9	Oil (paraffin)	0.8	Nitrogen	0.967
Ice	0.917	Water	1.00	Oxygen	1.105

lift a larger weight under water than he can possibly lift in the atmosphere. The upward force which any fluid exerts upon a body placed in it is called buoyant force.

The following experiment is illustrated in figure 2-2. The overflow can is filled up to the spout with water. The heavy metal cylinder is first weighed in still air and then is weighed while completely submerged in the water. The difference between the two weights is the buoyant force of the water. As the cylinder is lowered into the overflow can, the water is caught in the catch bucket. The volume of water which overflows equals the volume of the cylinder. (The volume of irregular shaped objects may be measured by this method.) If this experiment is performed carefully, the weight of the water displaced by the metal cylinder exactly equals the buoyant force of the water.

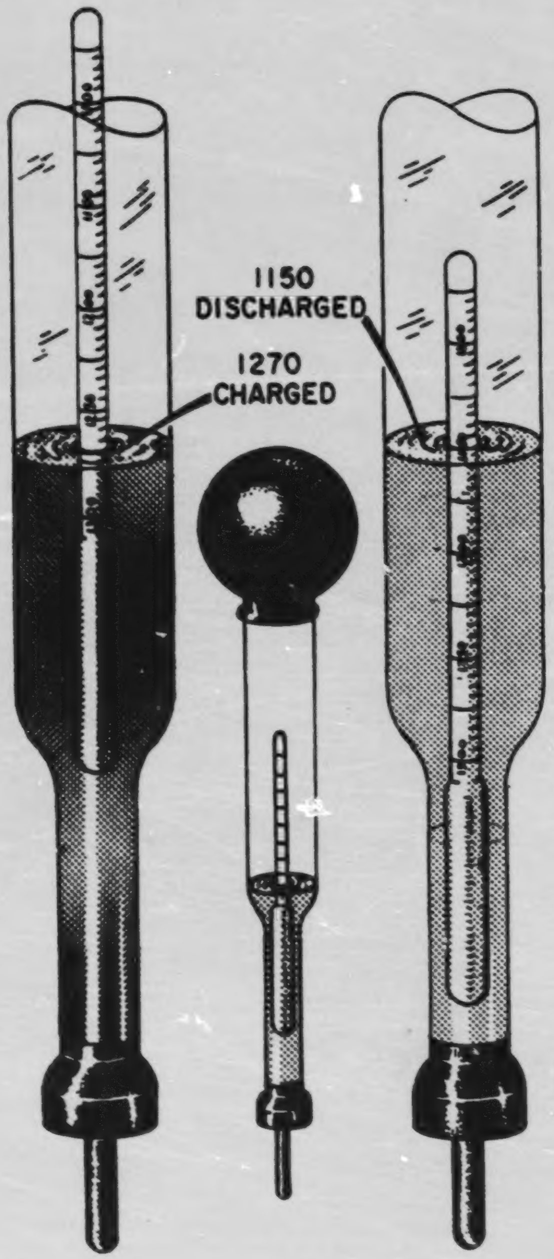
Experiments similar to this were performed by Archimedes (287-212 B.C.). As a result of his experiments he discovered that the buoyant force which a fluid exerts upon a submerged body is equal to the weight of the fluid the body displaces. This statement is referred to as Archimedes' principle. This principle applies to all fluids, gases as well as liquids. Just as water exerts a buoyant force on submerged objects, air exerts a buoyant force on objects submerged in it.

TEMPERATURE

As indicated previously, temperature is a dominant factor affecting the physical properties of fluids. It is of particular concern when calculating changes in the state of gases.

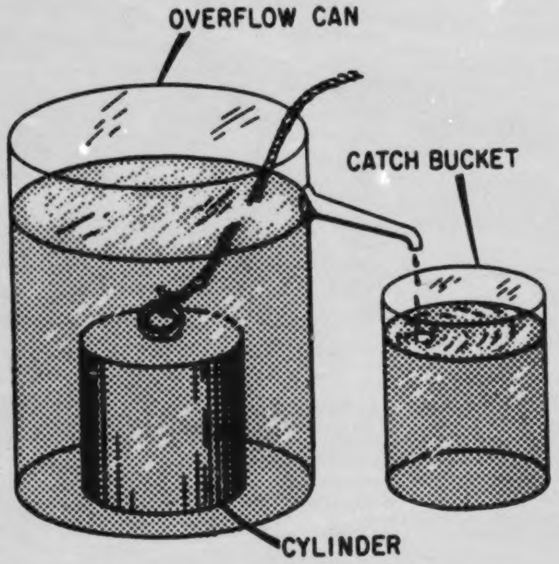
The three temperature scales used extensively are the Celsius (C), the Fahrenheit (F), and the absolute or Kelvin (K) scales. The Celsius scale (the centigrade scale has been renamed the Celsius scale in recognition of Anders Celsius, the Swedish astronomer who devised the scale) is constructed by using the freezing point and boiling points of water, under standard conditions, as fixed points of zero and 100, respectively, with 100 equal divisions between. The Fahrenheit scale uses 32° as the freezing point of water and 212° as the boiling point, and has 180 equal divisions between. The absolute or Kelvin scale is constructed with its zero point established as 273° C, or 459.4° F. The relations of the other fixed points of the scale are shown in figure 2-3.

Absolute zero, one of the fundamental constants of physics, is commonly used in the study of gases. It is usually expressed in terms of the Celsius scale. If the heat energy of a given gas sample could be progressively reduced, some temperature should be reached at which the motion of the



FP.1

Figure 2-1.—A hydrometer.



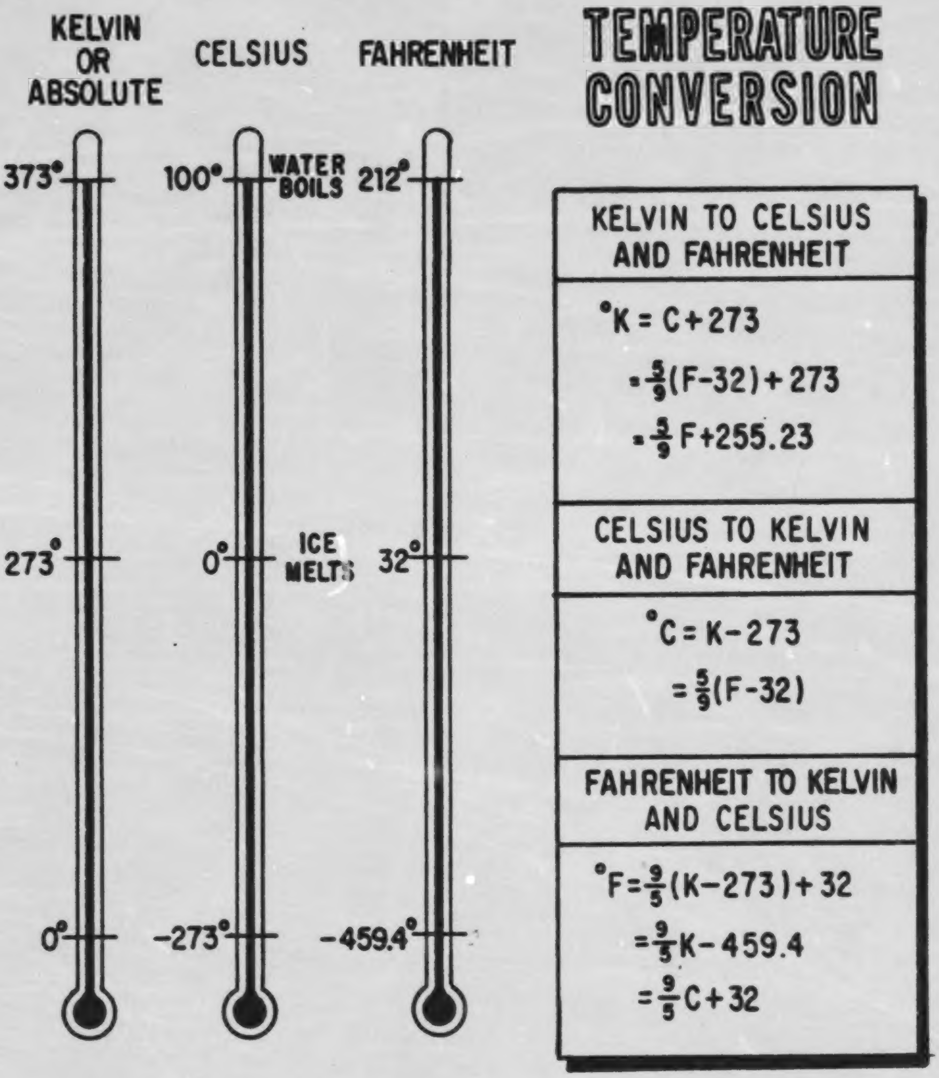
FP.2

Figure 2-2.—Measurement of buoyant force.

molecules would cease entirely. If accurately determined, this temperature could then be taken as a natural reference, or as a true "absolute zero" value.

Experiments with hydrogen indicated that if a gas were cooled to -273.16° C (used as -273° for most calculations), all molecular motion would cease and no additional heat could be extracted from the substance. Since this is the coldest temperature to which an ideal gas can be cooled, it is considered as absolute zero. When temperatures are measured with respect to the absolute zero reference, they are expressed as zero on the absolute or Kelvin scale. Thus, absolute zero may be expressed as 0° K, as -273° C, or as -459.4° F (-460° F for most calculations).

Personnel working with temperatures must always make sure which system of measurement is being used and how to convert from one to another. The conversion formulas are shown in figure 2-3. For purposes of calculations, the Rankine scale illustrated in figure 2-4 is commonly used to convert Fahrenheit to absolute. For Fahrenheit readings above zero, 460° is added. Thus, 72° F



TEMPERATURE CONVERSION

KELVIN TO CELSIUS AND FAHRENHEIT

$$°K = C + 273$$
$$= \frac{5}{9}(F-32) + 273$$
$$= \frac{5}{9}F + 255.23$$

CELSIUS TO KELVIN AND FAHRENHEIT

$$°C = K - 273$$
$$= \frac{5}{9}(F-32)$$

FAHRENHEIT TO KELVIN AND CELSIUS

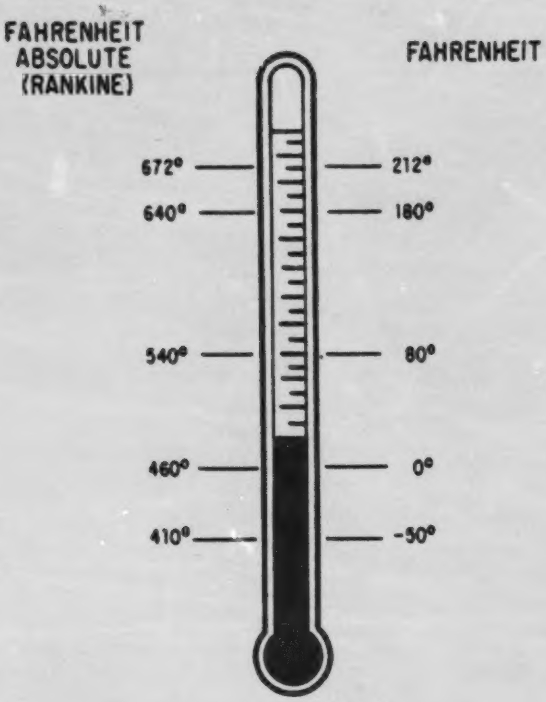
$$°F = \frac{9}{5}(K-273) + 32$$
$$= \frac{9}{5}K - 459.4$$
$$= \frac{9}{5}C + 32$$

FP.3

Figure 2-3.—Comparison of Fahrenheit, Celsius, and Kelvin temperature.

equals 460° plus 72° or 532° absolute. If the Fahrenheit reading is below zero, it is substracted from 460°. Thus, -40° F equals 460° minus 40° or 420° absolute. It should be pointed out that the Rankine scale does not indicate absolute temperature readings in accordance with the Kelvin scale, but these conversions may be used for the calculations of changes in the state of gases.

The Kelvin and Celsius scales are used more extensively in scientific work and, therefore, some technical manuals may use these scales in giving directions and operating instructions. The Fahrenheit scale is commonly



FP.4

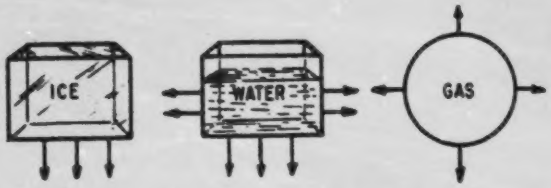
Figure 2-4.—Fahrenheit and absolute temperature compared (Rankine scale).

used in the United States and most people are familiar with it. Therefore, the Fahrenheit scale is used in most areas of this manual.

PRESSURE

The term pressure, as used throughout this manual, is defined as a force per unit volume. It is further defined in relation to other factors later in this chapter. Pressure is usually measured in pounds per square inch (psi). Sometimes pressure is measured in inches of mercury, or for very low pressure, inches of water.

Pressure may be exerted in one direction, several directions, or in all directions. (See fig. 2-5.) The ice (a solid) exerts pressure downward only. Water (a liquid) exerts pressure on all surfaces with which it comes in contact. Gas exerts pressure in all directions.



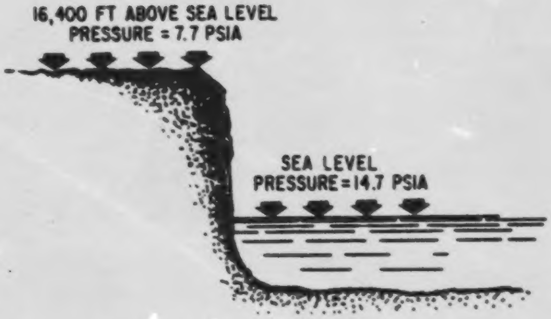
FP.5

Figure 2-5.—Exertion of pressure.

Gas exerts pressure on all sides because it completely fills the container.

Atmospheric Pressure

The atmosphere is the whole mass of air surrounding the earth. While it extends upward for about 500 miles, the section of primary interest is that portion of the air which rests on the earth's surface and extends upward for about 7 1/2 miles. This layer is called the troposphere. The higher one ascends in the troposphere, the lower the pressure. This is because air has weight. If a column of air 1-inch square extending all the way to the "top" of the atmosphere could be weighed, this column of air would weigh approximately 14.7 pounds at sea level. Thus, atmospheric pressure at sea level is approximately 14.7 pounds per square inch (psi). (See fig. 2-6.)



FP.6

Figure 2-6.—Atmospheric pressure.

As one ascends, the atmospheric pressure decreases approximately 1.0 psi for every 2,343 feet. However, below sea level, in excavations and depressions, atmospheric pressure increases. Pressures under water differ from those under air only because the weight of the water must be added to the pressure of the air.

Atmospheric pressure can be measured by any of several methods. The common laboratory method employs the mercury column barometer. A mercury column consists of a glass tube approximately 34 inches in length, sealed at one end, then completely filled with mercury, and inverted in an open container partially filled with mercury. (See fig. 2-7.)

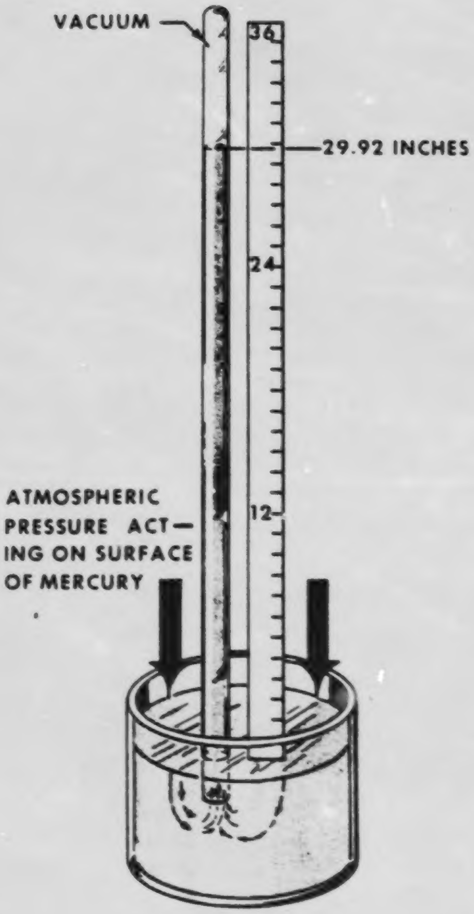
The mercury in the tube settles down, leaving an evacuated space in the upper end of the tube. The height of the mercury column serves as an indicator of atmospheric pressure. At sea level and at a temperature of 0° C, the height of the mercury column is approximately 30 inches or 76 centimeters. This represents a pressure of approximately 14.7 psi. The 30-inch column is used as a reference standard.

At higher levels, the atmospheric pressure on the surface of the mercury in the open container is less than at sea level; hence, the column of mercury in the tube settles lower. These variations in the height of the mercury column represent changes in the atmospheric pressure which may be calibrated in terms of altitude with reference to sea level.

Another device used to measure atmospheric pressure is the aneroid barometer. (See fig. 2-8.) The term "aneroid" means without fluid. The aneroid barometer, then, is a fluidless barometer, utilizing the change in shape of an evacuated metal cell to measure variations in atmospheric pressure.

The aneroid barometer gets its name from the pressure-sensitive element used in the instrument. An aneroid is a thin-walled metal capsule or cell, sometimes called a diaphragm, that has been either partially or completely evacuated of air. This thin metal moves in or out with the variation of pressure on its external surface. This movement is transmitted through a system of levers to a pointer, which indicates the pressure.

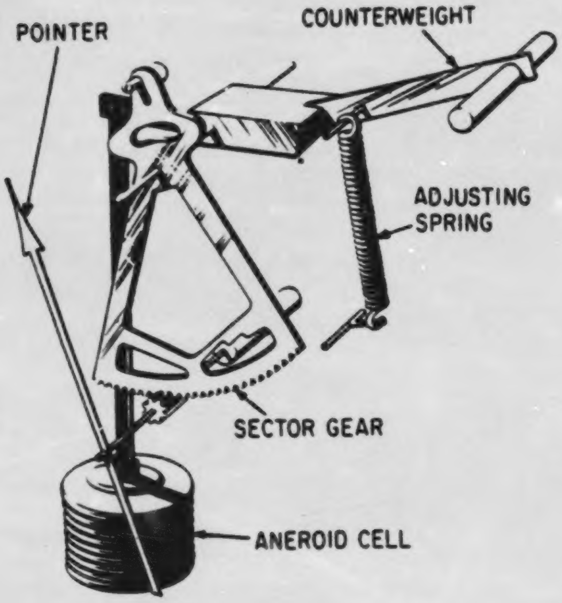
The atmospheric pressure does not vary uniformly with altitude. It changes more rapidly at lower altitudes because of the compressibility of the air, which causes the air layers close to the earth's surface to be compressed by the air masses above them. This effect, however, is partially counteracted by contraction of the upper layers due to cooling. The cooling tends to increase the density of the air.



FP.7

Figure 2-7.—Measurement of atmospheric pressure—mercury barometer.

Atmospheric pressures are quite large, but in most instances practically the same pressure is present on all sides of objects so that no single surface is subjected to a great load.



FP.8

Figure 2-8.—Simple diagram of the aneroid barometer.

The effects of atmospheric pressure on fluids is covered later in this chapter.

Absolute Pressure

As stated previously, absolute temperature is used in the calculation of changes in the state of gas. It is also necessary to use absolute pressure for these and other calculations.

Absolute pressure is measured from absolute zero pressure rather than from normal or atmospheric pressure (approximately 14.7 psi). Gage pressure is used on all ordinary gages, and indicates pressure in excess of atmospheric. Therefore, absolute pressure is equal to atmospheric pressure plus gage pressure. For example, 100 psi gage pressure (psig—meaning pounds per square inch gage) equals 100 psi plus 14.7 psi or 114.7 psi absolute pressure (psia—meaning pounds per square inch absolute).

INCOMPRESSIBILITY AND EXPANSION OF LIQUIDS

Liquids can be only slightly compressed; that is, the reduction of the volume which they occupy, even under extreme pressure, is very small. If a pressure of 100 psi is applied to a body of water, the volume will decrease only 3/10,000 of its original volume. It would take a force of 32 tons to reduce its volume 10 percent. When this force is removed, the water immediately returns to its original volume. Since other liquids behave in about the same manner as water, liquids are usually considered incompressible.

NOTE: In some applications of hydraulics where extremely close tolerances are required, the compressibility of liquids must be considered in the design of the system. In this manual, however, liquids are considered to be incompressible.

Almost all forms of matter expand when heated. this action is normally referred to as thermal expansion. The amount of expansion varies with the substance. In general, liquids expand much more than solids. For example, when a liter (1,000 cubic centimeters) of water is heated from 0° to 100° C, it increases approximately 43 cubic centimeters in volume; whereas a block of steel of the same volume would expand only 3 cubic centimeters. All liquids do not expand the same amount for a certain increase of temperature. If two flasks are placed in a heated vessel, and if one of these flasks is filled with water and the other with alcohol, it will be found that the alcohol expands much more than the water for the same rise in temperature. Most oils expand more than water. Hydraulic systems contain provisions for compensating for this increase of volume in order to prevent breakage of the equipment.

COMPRESSIBILITY AND EXPANSION OF GASES

As mentioned previously, two of the major differences between liquids and gases are in respect to compressibility and expansion. While liquids are practically incompressible, gases are highly compressible. Gases tend to completely fill any container, while liquids fill a container only to the extent of their normal volume.

Although both liquids and gases expand when heated, gases expand much more than liquids (approximately nine times as much as water). Unlike liquids, all gases expand approximately the same. Because of these characteristics, there are several laws concerning the compressibility and expansion of gases. These laws are discussed in the following paragraphs.

Kinetic Theory of Gases

The simple structure of gases make them readily adaptable to mathematical analysis from which has evolved a detailed theory of gases. This is called the kinetic theory of gases. The theory assumes that a body of gas is composed of identical molecules (see glossary) which behave like minute elastic spheres, spaced relatively far apart and continuously in motion.

The degree of molecular motion is dependent upon the temperature of the gas. Since the molecules are continuously striking against each other and against the walls of the container, an increase in temperature with the resulting increase in molecular motion causes a corresponding increase in the number of collisions between the molecules. The increased number of collisions results in an increase in pressure, because a greater number of molecules strike against the walls of the container in a given unit of time.

If the container were an open vessel, the gas would tend to expand and overflow from the container. However, if the container is sealed and possesses elasticity (such as a rubber balloon), the increased pressure causes the container to expand.

For example, when making a long drive on a hot day, the pressure in the tires of an automobile increases and a tire which appeared to be somewhat "soft" in cool morning temperature may appear normal at a higher midday temperature.

Such phenomena as these have been explained and set forth in the form of laws pertaining to gases and tend to support the kinetic theory.

At any given instant, some molecules of a gas are moving in one direction, some are moving in another direction; some are traveling fast while some are traveling slowly; some may even be in a state of rest. The combined effect of these varying velocities, corresponds to the temperature of the gas. In any considerable amount of gas, there are so many molecules present that in accordance with the "laws of probability" some average velocity can be found which, if it were possessed by every molecule in the gas, would produce the same effect at a given temperature as the total of the many varying velocities.

Boyle's Law

As previously stated, compressibility is an outstanding characteristic of gases. The English scientist Robert Boyle was among the first to study this characteristic, which he called the "springiness of air." By direct measurement, he discovered that when the temperature of an enclosed sample of gas was kept constant and the pressure doubled, the volume was reduced to half the former value; as the applied pressure was decreased, the resulting volume increased. From these observations, he concluded that for a constant temperature the product of the volume and pressure of an enclosed gas remains constant. This became Boyle's law, which is normally stated: "The volume of an enclosed dry gas varies inversely with its pressure, provided the temperature remains constant."

This law can be demonstrated by confining a quantity of gas in a cylinder which has a tightly fitted piston. A force is then applied to the piston so as to compress the gas in the cylinder to some specific volume. When the force applied to the piston is doubled, the gas is compressed to one-half its original volume, as indicated in figure 2-9.

In equation form, this relationship may be expressed either

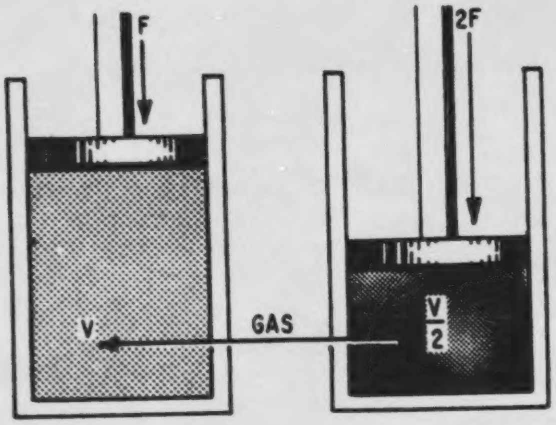
$$V_1P_1 = V_2P_2$$

or

$$\frac{V_1}{V_2} = \frac{P_2}{P_1}$$

when V_1 and P_1 are the original volume and pressure, and V_2 and P_2 are the revised volume and pressure.

Example of Boyle's law: 4 cubic feet of nitrogen are under a pressure of 100 psi (gage). The nitrogen is allowed to expand



FP.9

Figure 2-9.—Gas compressed to half its original volume by a double force.

to a volume of 6 cubic feet. What is the new gage pressure? Remember to convert gage pressure to absolute pressure by adding 14.7.

Formula or equation:

$$V_1P_1 = V_2P_2$$

Substituting:

$$4 \times (100 + 14.7) = 6 \times P_2$$

$$P_2 = \frac{4 \times 114.7}{6}$$

$$P_2 = 76.47 \text{ psi absolute}$$

Converting absolute pressure to gage pressure:

$$\begin{array}{r} 76.47 \\ -14.7 \\ \hline 61.77 \end{array}$$ psi gage pressure—Answer.

Changes in the pressure of a gas also affects the density. As the pressure increases, its volume decreases; however, there is no change in the weight of the gas. Therefore, the weight per unit volume (density) increases. So it follows that the density of a gas varies directly as the pressure, if the temperature is constant.

Charles' Law

The French scientist Jacques Charles provided much of the foundation for the modern kinetic theory of gases. He found that all gases expand and contract in direct proportion to the change in the absolute temperature, provided the pressure is held constant. Expressed in equation form this part of the law may be expressed

$$V_1T_2 = V_2T_1,$$

or

$$\frac{V_1}{V_2} = \frac{T_1}{T_2}$$

where V_1 and V_2 refer to the original and final volumes, and T_1 and T_2 indicate the corresponding absolute temperatures.

Since any change in temperature of a gas causes a corresponding change in volume, it is reasonable to expect that if a given sample of a gas were heated while confined within a given volume, the pressure should increase. By actual experiment, it was found that for each 1° C increase in temperature the increase in pressure was approximately 1/273 of the pressure at 0° C. Because of this fact, it is normal practice to state this relationship in terms of absolute temperature. In equation form, this part of the law becomes

$$P_1T_2 = P_2T_1,$$

or

$$\frac{P_1}{P_2} = \frac{T_1}{T_2}$$

In words, this equation states that with a constant volume, the absolute pressure of a gas varies directly with the absolute temperature.

Examples of Charles' law: A cylinder of gas under a pressure of 1,800 psig at 70° F is left out in the sun in the tropics and heats up to a temperature of 130° F. What is the new pressure within the cylinder? The pressure and temperature must be converted to absolute pressure and temperature.

Formula or equation:

$$\frac{P_1}{P_2} = \frac{T_1}{T_2}$$

Using the Rankine system:

70° F = 530° absolute

130° F = 590° absolute

Substituting:

$$\frac{1,800 + 14.7}{P_2} = \frac{530}{590}$$

Then:

$$P_2 = \frac{(590)\quad(1,814.7)}{530}$$

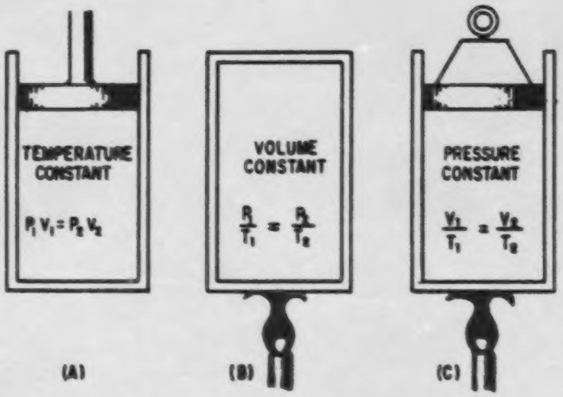
$$P_2 = 2,020 \text{ psia}$$

Converting absolute pressure to gage pressure:

$$\begin{array}{r} 2,020.0 \\ -14.7 \\ \hline 2,005.3 \end{array} \text{ psig—Answer.}$$

General Gas Law

The facts concerning gases discussed in the preceding paragraphs are summed up and illustrated in figure 2-10. Boyle's law is expressed in (A) of the figure, while the effects of temperature changes on pressure and volume (Charles' law) are illustrated in (B) and (C), respectively.



FP.10

Figure 2-10.—The general gas law.

By combining Boyle's law and Charles' law, a single expression can be derived which includes all the information contained in both. It is referred to as the GENERAL GAS LAW. It states that the product of the initial pressure, initial volume, and new temperature (absolute scale) of an enclosed gas is equal to the product of the new pressure, new volume, and initial temperature. It is a mathematical statement whereby many gas problems can be solved involving the principles of Boyle's law and/or Charles' law. The equation may be expressed as

$$P_1V_1T_2 = P_2V_2T_1$$

or

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$$

NOTE: The capital P and T signify absolute pressure and temperature, respectively.

It can be seen by examination of figure 2-10 that the three equations are special cases of the general equation. Thus, if the temperature remains constant, T_1 equals T_2 and both can be eliminated from the general formula, which then reduces to the form shown in (A). When the volume remains constant, V_1 equals V_2, thereby reducing the general equation to the form given in (B). Similarly, P_1 is equated to P_2 for constant pressure, and the equation then takes the form given in (C).

The general gas law applies with exactness only to "ideal" gases in which the molecules are assumed to be perfectly elastic. However, it describes the behavior of actual gases with sufficient accuracy for most practical purposes.

Two examples of the general equation follow:

1. Two cubic feet of a gas at 75 psig and 80° F are compressed to a volume of 1 cubic foot and then heated to a temperature of 300° F. What is the new gage pressure?

Formula or equation:

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$$

Using the Rankine system:

80° F = 540° absolute

300° F = 760° absolute

Substituting:

$$\frac{(75 + 14.7)\ (2)}{540} = \frac{P_2\ (1)}{760}$$

Then:

$$\frac{179.4}{540} = \frac{P_2}{760}$$

$$P_2 = \frac{(179.4)\ (760)}{540}$$

$$P_2 = 252.5 \text{ psia}$$

Converting absolute pressure to gage pressure:

$$\begin{array}{r} 252.5 \\ -14.7 \\ \hline 237.8 \end{array} \text{ psig—Answer.}$$

2. Four cubic feet of a gas at 75 psig and 80° F are compressed to 237.8 psig and heated to a temperature of 300° F. What is the volume of the gas resulting from these changes?

Formula or equation:

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$$

Using the Rankine system:

$$80° \text{ F} = 540° \text{ absolute}$$
$$300° \text{ F} = 760° \text{ absolute}$$

Substituting:

$$\frac{(75 + 14.7)\ (4)}{540} = \frac{(237.8 + 14.7)\ V_2}{760}$$

Then:

$$\frac{(89.7)\ (4)}{540} = \frac{(252.5)\ V_2}{760}$$

$$V_2 = \frac{358.8 \times 760}{540 \times 252.5}$$

$$V_2 = 2 \text{ cubic feet—Answer.}$$

Avogadro's Law

An Italian physicist, Avogadro, conceived the theory that "at the same temperature and pressure, equal volumes of different gases contain equal numbers of molecules." This theory was proven by experiment and found to agree with the kinetic theory, so it has come to be known as Avogadro's Law.

Dalton's Law

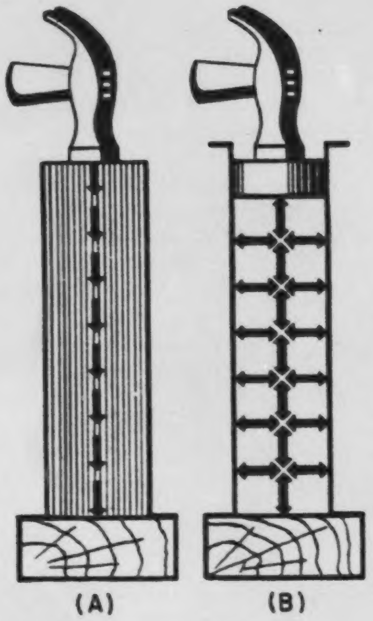
If a mixture of two or more gases which do not combine chemically is placed in a container, each gas expands throughout the total space and the absolute pressure of each gas is reduced to a lower value, called a partial pressure. This reduction is in accordance with Boyle's law. The pressure of the mixture of these two gases is equal to the sum of the partial pressures. This fact was discovered by Dalton, an English physicist, and is set forth as Dalton's law. The law states that "a mixture of several gases which do not react chemically exerts a pressure equal to the sum of the pressures which the several gases would exert separately if each were allowed to occupy the entire space alone at the given temperature."

TRANSMISSION OF FORCES THROUGH FLUIDS

When the end of a solid bar is struck, the main force of the blow is carried straight through the bar to the other end. (See fig. 2-11 (A).) This happens because the bar is rigid. The direction of the blow almost entirely determines the direction of the transmitted force. The more rigid the bar, the less force is lost inside the bar or transmitted outward at right angles to the direction of the blow.

When a force is applied to the end of a column of confined liquid (fig. 2-11 (B)), it is transmitted straight through to the other end and also equally and undiminished in every direction throughout the column—forward, backward, and sideways—so that the containing vessel is literally filled with pressure.

If a gas is used instead of a liquid, the force is transmitted in the same manner. The one difference is that gas, being highly compressible, provides a much less rigid force than the liquid, which is practically incompressible. (This is the main difference in the action of liquids and gases in fluid power systems.)

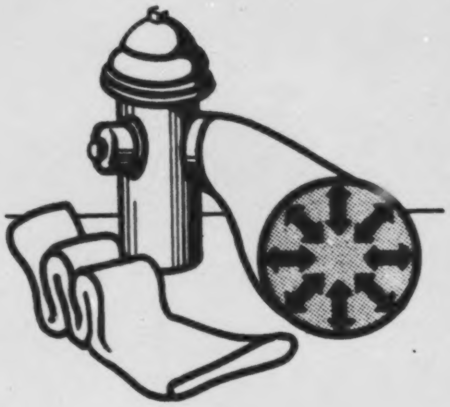


FP.11
Figure 2-11.—Transmission of force: (A) Solid; (B) fluid.

An example of this distribution of force is illustrated in figure 2-12. The flat hose takes on a circular cross section when it is filled with water under pressure. The outward push of the water is equal in every direction. The automobile tire and the toy balloon are examples of this distribution of force through the use of gases.

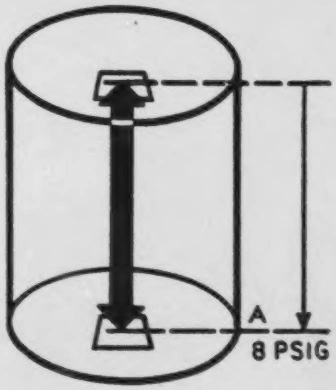
PASCAL'S LAW

As related in chapter 1, the foundations of modern hydraulics, and pneumatics, were established in 1653 when Pascal discovered that pressure set up in a fluid acts equally in all directions. This pressure acts at right angles to the containing surfaces. Thus in figure 2-13, if the liquid standing on a square inch (A) at the bottom of the container weighs 8 pounds (disregarding the atmospheric pressure acting on the surface of the liquid), a pressure of 8 psig is exerted in every direction at (A). The liquid resting on (A) pushes equally downward and outward. The liquid on every square inch of the bottom surface is pushing downward and outward in the same way, so that the pressures on different areas are in balance.



FP.12
Figure 2-12.—Distribution of force.

At the edge of the bottom the pressures act against the walls of the container, which must be strong enough to resist them with a force exactly equal to the force of the liquid. Every square inch of the bottom of the container must also be strong enough to resist the downward pressure of the liquid resting on it. The same balance of pressures



FP.13
Figure 2-13.—Pressure acting on a container.

exists at every other level in the container, though of lesser pressures as one approaches the surface. Therefore, the liquid remains at rest—it does not leak out and the container does not collapse. The pressure of the liquid decreases as one approaches the surface because the volume of liquid and, therefore, the weight above each square inch decreases. This is similar to the decrease in atmospheric pressure with increase in altitude, as discussed previously.

One of the consequences of Pascal's law is that the shape of the container in no way alters pressure relations. Thus in figure 2-14, if the pressure due to the weight of the liquid at one point on the horizontal line (H) is 8 psi, the pressure is 8 psi everywhere at level (H) in the system.

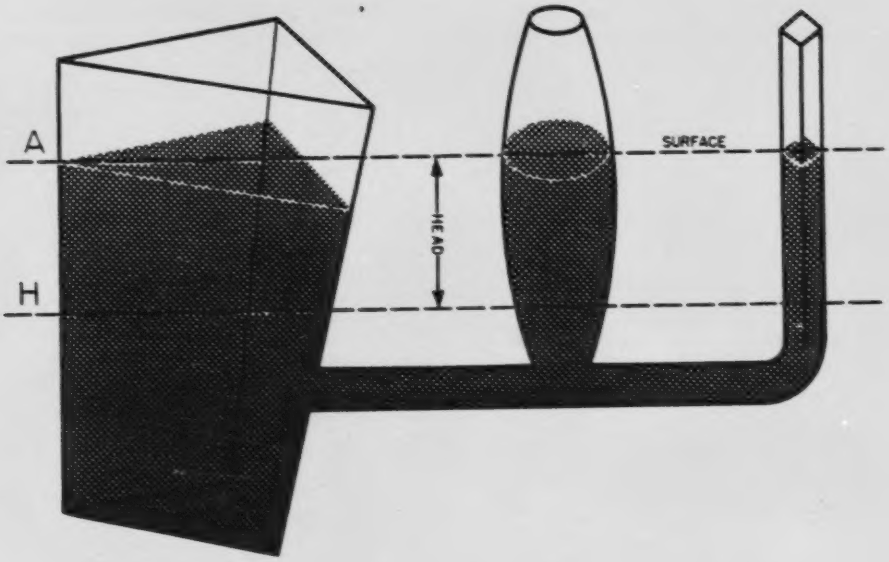
Pressure due to the weight of a fluid depends, at any level, upon the vertical height of the fluid from the level to the surface of the fluid. The vertical distance between two horizontal levels in a fluid is known as the head of the fluid. In figure 2-14, the liquid head of all points on the level (H) with respect to the surface is indicated.

Pressure due to fluid head also depends upon the density of the fluid. Water, for example, weighs 62.4 pounds per cubic foot or 0.036 pound per cubic inch, while certain oil might weigh 55 pounds per cubic foot, or 0.032 pound per cubic inch. It would take 222 inches of head, using water to produce a pressure of 8 psi and 252 inches using oil. (See fig. 2-15.)

This fluid head, which is sometimes referred to as gravity head or altitude head, also applies to gases. As discussed previously, atmospheric pressure at any given altitude is the result of the weight of the air above that altitude. In this case, however, several miles of vertical height are required to produce approximately 14.7 psi at sea level. Therefore, when considering a cubic foot of gas, the gravity head is negligible. For example, a cubic foot of compressed air (100 psi) at 70° F produces a gravity head which is less than 1 percent of that produced by a cubic foot of water.

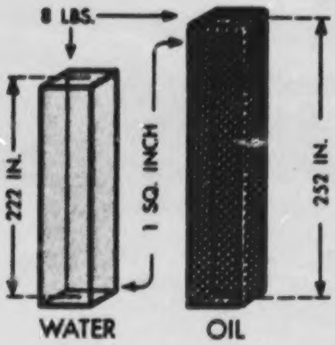
FORCE AND PRESSURE

The terms force and pressure are used frequently in the preceding paragraphs. In order to understand how Pascal's law is applied



FP.14

Figure 2-14.—Pressure relationship with shape.



FP.15

Figure 2-15.—Pressure and density relationship.

to fluid power, a distinction must be made between these terms. Force may be defined as a push or pull. It is the push or pull exerted against the total area of a particular surface and is expressed in pounds. As previously stated, pressure is the amount of force on a unit area of the surface acted upon. In hydraulics and pneumatics, this unit area is expressed in pounds per square inch. Thus pressure is the amount of force acting upon 1 square inch of area.

Computing Force, Pressure, and Area

A formula, similar to those used in conjunction with the gas laws, is used in computing force, pressure, and area in fluid power systems. Although there appears to be three formulas, there is only one formula, which may be written in three variations. In this formula, P refers to pressure, F indicates force, and A represents area.

Force equals pressure times area. Thus, the formula is written

$$F = P \times A$$

Pressure equals force divided by the area. By rearranging the formula, this statement may be condensed into

$$P = \frac{F}{A}$$

Since area equals force divided by pressure, the formula is written

$$A = \frac{F}{P}$$

Figure 2-16 illustrates a device for recalling the different variations of this formula. Any letter in the triangle may be expressed as the product or quotient of the other two, depending upon its position within the triangle.

For example, to find area, consider the letter A as being set off to itself, followed by an equal sign. Now look at the other two letters. The letter F is above the letter P; therefore,

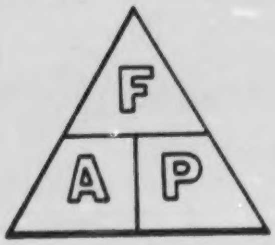
$$A = \frac{F}{P}$$

In order to find pressure, consider the letter P as being set off to itself, and look at the other two letters. The letter F is above the letter A; therefore,

$$P = \frac{F}{A}$$

Likewise, to find force, consider the letter F as being set off to itself. The letters P and A are side by side; therefore, F = P x A.

NOTE: Sometimes the area may not be expressed in square inches. If it is a rectangular surface, the area may be found by multiplying the length (in inches) by the width (in inches). The majority of areas to be considered in these calculations are circular in shape. Either the radius or the diameter may be given. The radius in inches must be known to find the area. The radius is one-half the diameter. Then, the formula for finding the area of a circle is used. This is written



FP.16

Figure 2-16.—Device for determining the arrangement of the force, pressure, and area formula.

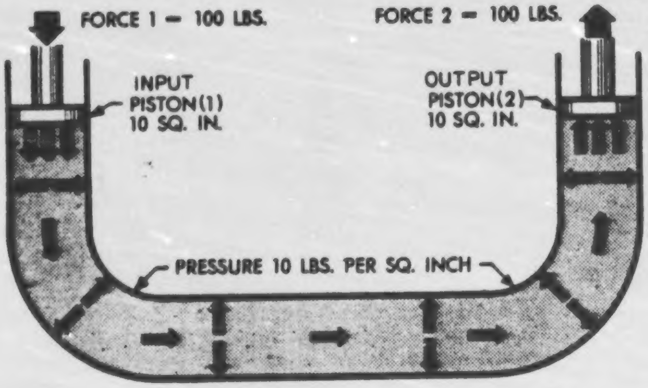
$A = \pi r^2$, where, A is the area, π is 3.1416 (3.14 or 3 1/7 for most calculations), and r^2 indicates the radius squared.

PRESSURE AND FORCE IN FLUID POWER SYSTEMS

In accordance with Pascal's law, any force applied to a confined fluid is transmitted in all directions throughout the fluid regardless of the shape of the container. Consider the effect of this in the system shown in figure 2-17. This is in reality a modification of figure 2-11 (B) in which the column of fluid is curved back upward to its original level, with a second piston at this point. If there is a resistance on the output piston (2) and the input piston is pushed downward, a pressure is created through the fluid, which acts equally at right angles to surfaces in all parts of the container.

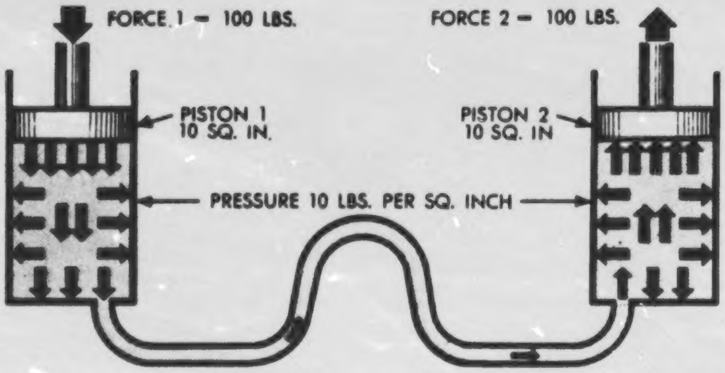
Referring to figure 2-17, if the force (1) is 100 pounds and the area of the input piston (1) is 10 square inches, then the pressure in the fluid is 10 psi $\left(\frac{100}{10}\right)$. (NOTE: It must be emphasized that this fluid pressure cannot be created without resistance to flow, which, in this case, is provided by the 100 pound force acting against the top of the output piston (2).) This pressure acts on piston (2), so that for each square inch of its area it is pushed upward with a force of 10 pounds. In this case, a fluid column of uniform cross section is considered so that the area of the output piston (2) is the same as the input piston (1), or 10 square inches. Therefore, the upward force on the output piston (2) is 100 pounds, the same as was applied to the input piston (1). All that has been accomplished in this system was to transmit the 100-pound force around a bend. However, this principle underlies practically all mechanical applications of fluid power.

At this point it should be noted that since Pascal's law is independent of the shape of the container, it is not necessary that the tube connecting the two pistons should be the full area of the pistons. A connection of any size, shape, or length will do, so long as an unobstructed passage is provided. Therefore,


FORCE 1 — 100 LBS.
FORCE 2 — 100 LBS.
INPUT PISTON(1) 10 SQ. IN.
OUTPUT PISTON(2) 10 SQ. IN.
PRESSURE 10 LBS. PER SQ. INCH

FP.17

Figure 2-17.—Force transmitted through fluid.


FORCE 1 — 100 LBS.
FORCE 2 — 100 LBS.
PISTON 1
10 SQ. IN.
PISTON 2
10 SQ. IN
PRESSURE 10 LBS. PER SQ. INCH

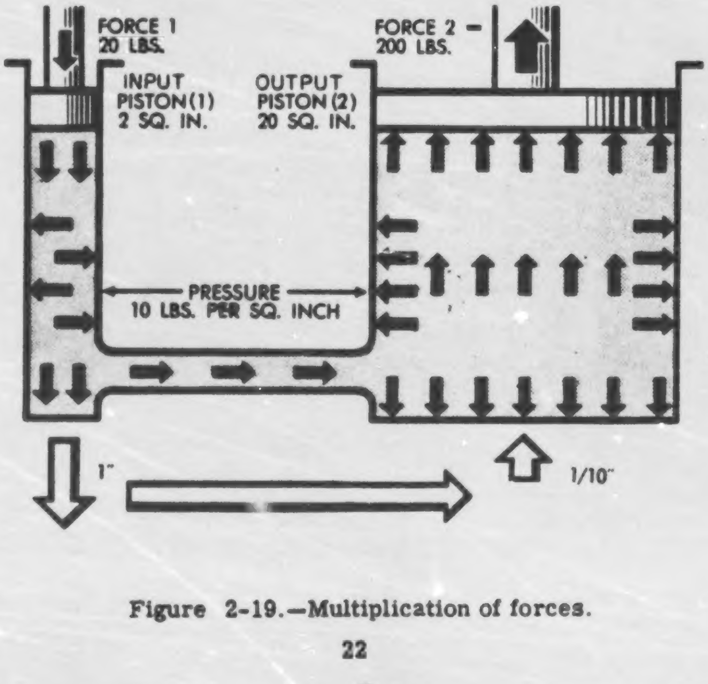
FP.18

Figure 2-18.—Transmitting force through small pipe.

the system shown in figure 2-18, wherein a relatively small, bent pipe connects two cylinders, will act exactly the same as that shown in figure 2-17.

Multiplication of Forces

In figures 2-17 and 2-18 the systems contain pistons of equal area wherein the output force is equal to the input force. Consider the situation in figure 2-19, where the input piston is much smaller than the output piston. Assume that the area of the input piston (1) is 2 square inches. With a resistant force on piston (2), a downward force of 20 pounds acting on piston (1) creates 10 psi $\left(\frac{20}{2}\right)$ in the fluid. Although this force


FORCE 1
20 LBS.
FORCE 2 —
200 LBS.
INPUT
PISTON(1)
2 SQ. IN.
OUTPUT
PISTON(2)
20 SQ. IN.
PRESSURE
10 LBS. PER SQ. INCH
1"
1/10"

FP.19

Figure 2-19.—Multiplication of forces.

is much smaller than the applied force in figures 2-17 and 2-18, the pressure is the same. This is because the force is concentrated on a relatively small area.

This pressure of 10 psi acts on all parts of the fluid container, including the bottom of the output piston (2). The upward force on the output piston (2) is therefore 10 pounds for each of its 20 square inches of area, or 200 pounds (10 x 20). In this case, the original force has been multiplied tenfold while using the same pressure in the fluid as before. In any system with these dimensions, the ratio of output force to input force is always ten to one, regardless of the applied force. For example, if the applied force of the input piston (1) is 50 pounds, the pressure in the system is increased to 25 psi. This will support a resistant force of 500 pounds on the output piston (2).

The system works the same in reverse. Consider piston (2) as the input and piston (1) as the output. Then the output force will always be one-tenth the input force. Sometimes such results are desired.

Therefore, if two pistons are used in a fluid power system, the force acting on each is directly proportional to its area, and the magnitude of each force is the product of the pressure and its area.

Differential Areas

Consider the special situation shown in figure 2-20. Here, a single piston (1) in a cylinder (2) has a piston rod (3) attached to one side of the piston. The piston rod extends out of one end of the cylinder. Fluid under pressure is admitted to both ends of the cylinder equally through the pipes (4, 5, and 6). The opposed faces of the piston (1) behave like two pistons acting against each other. The area of one face is the full cross-sectional area of the cylinder, say 6 square inches, while the area of the other face is the area of the cylinder minus the area of the piston rod, which is 2 square inches. This leaves an effective area of 4 square inches on the right face of the piston. The pressure on both faces is the same, in this case, 20 psi. Applying the rule just stated, the force pushing the piston to the right is its area times the pressure, or 120 pounds (20 x 6). Likewise, the force pushing the piston to the left is its area times the pressure, or 80 pounds (20 x 4). Therefore, there is a net unbalanced force of 40 pounds acting to the right, and the piston will move in that direction. The net effect is the same as if the piston and cylinder were just the size of the piston rod, since all other forces are in balance.

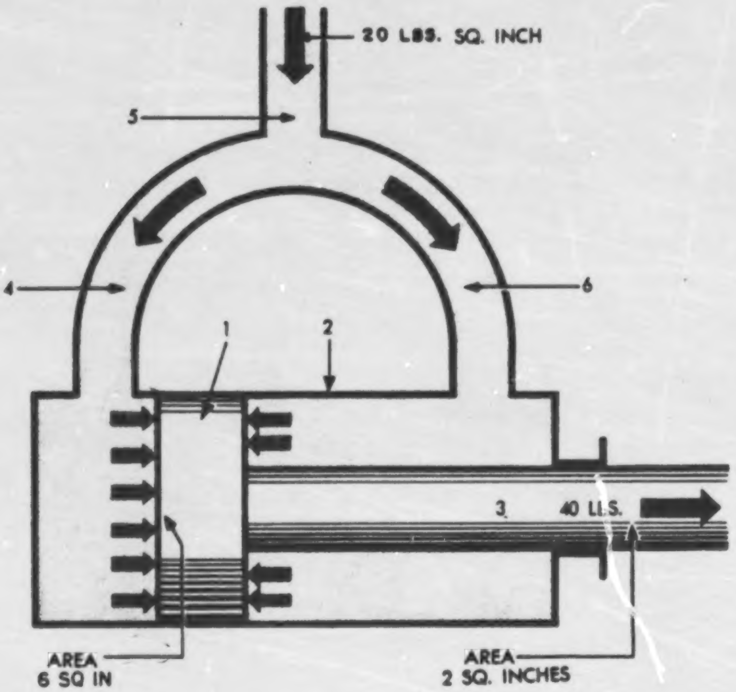
Volume and Distance Factors

In the systems illustrated in figures 2-17 and 2-18, the pistons have areas of 10 square inches. Since the areas of the input and output pistons are equal, a force of 100 pounds on the input piston will support a resistant force of 100 pounds on the output piston. At this point the pressure of the fluid is 10 psi. A slight force, in excess of 100 pounds, on the input piston will increase the pressure of the fluid, which will, in turn, overcome the resistance force. Assume that the input piston is forced downward 1 inch. This displaces 10 cubic inches of fluid. Since liquid is practically incompressible, this volume must go some place. In the case of a gas, it will compress momentarily, but will eventually expand to its original volume, at 10 psi. This is provided, of course, that the 100 pounds of force is still acting on the input piston. Thus, this volume of fluid moves the output piston. Since the area of the output piston is likewise 10 square inches, it moves 1 inch upward in order to accommodate the 10 cubic inches of fluid. The pistons are of equal areas, and will therefore move equal distances, though in opposite directions.

Applying this reasoning to the system in figure 2-19, it is obvious that if the input piston (1) is pushed down 1 inch, only 2 cubic inches of fluid is displaced. In order to accommodate these 2 cubic inches of fluid the output piston (2) will have to move only one-tenth of an inch, because its area is 10 times that of the input piston (1). This leads to the second basic rule for two pistons in the same fluid power system, which is that the distances moved are inversely proportional to their areas.

Effects of Atmospheric Pressure

Atmospheric pressure, described previously, obeys Pascal's law the same as pressure set up in fluids. As illustrated in figure 2-13,



FP.20

1. Piston. 2. Cylinder. 3. Piston rod. 4. Pipe. 5. Pipe. 6. Pipe

Figure 2-20.—Differential areas on a piston.

pressures, due to liquid head, are distributed equally in all directions. This is also true of atmospheric pressures. The situation is the same if these pressures act on opposite sides of any surfaces, or through fluids. In figure 2-21 (A) the suspended sheet of paper is not torn by atmospheric pressure, as it would be by an unbalanced force of 14.7 psi, because atmospheric pressure acts equally on both sides of the paper.

In figure 2-21 (B), atmospheric pressure acting on the surface of the liquid is transmitted equally throughout the liquid to the walls of the container, but is balanced by the same pressure acting directly on the outer walls of the container. In view (C) of figure 2-21, atmospheric pressure acting on the surface of one piston is balanced by the same pressure acting on the surface of the other. The different areas of the two surfaces make no difference, since for a unit of area, pressures are in balance.

Vacuum and Partial Vacuum

When an individual drinks soda through a straw, he removes some of the air from the straw. This disturbs the balance of pressures which was prevailing between the liquid in the glass and the liquid in the straw. This results in unbalanced pressures, and atmospheric pressure on the liquid in the glass pushes the soda up into the straw until a new balance is reached. The soda can be held at a certain level in the straw. This level will always be where the pressure of the head of liquid exactly equals the difference between the pressure in the straw and that on the surface of the liquid in the glass. (See fig. 2-22.) When the straw is removed from the person's

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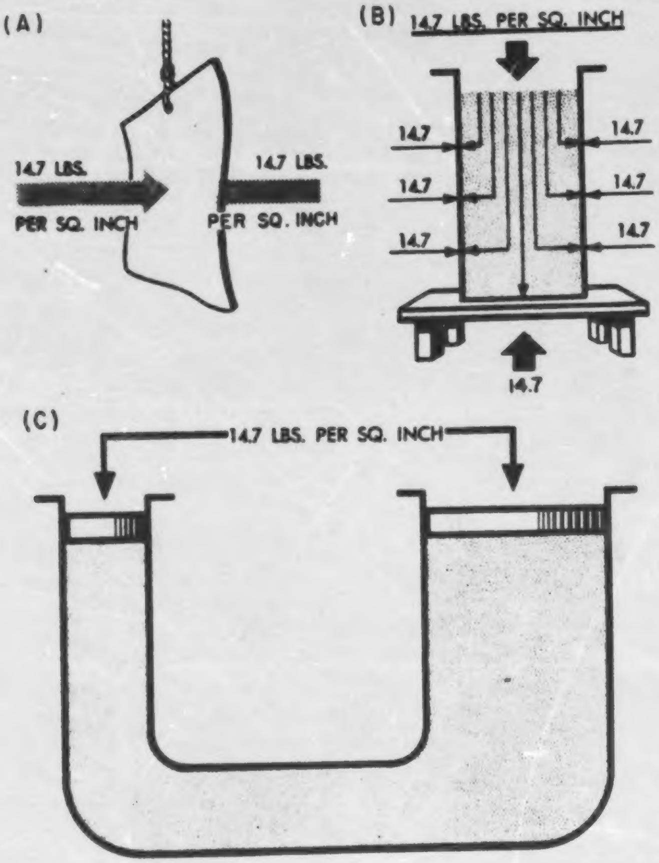

FP.21

Figure 2-21.—Effects of atmospheric pressure.

mouth, the soda in the straw is subject to the same pressure as that on the surface of the liquid in the glass. This causes the liquid in the straw to return to its original level, which is the same as that in the glass.

A partial vacuum is produced in the straw—that is, a pressure less than the prevailing atmospheric pressure. The theoretical limit of this process would be a condition of zero pressure—a complete vacuum. In actual practice, however, it is impossible to produce a complete vacuum.

This action takes place in the power supply for fluid power systems. As the pump or compressor moves the fluid into the system, a low pressure area (partial vacuum) is developed at the inlet port. This allows atmospheric pressure to push the fluid into the inlet port of the pump or compressor. This action is discussed in greater detail in chapters 4 and 8.

INPUT AND OUTPUT RELATIONS

As illustrated in figure 2-19, an increase in output force is accompanied by a decrease in the distance traveled in exactly the same

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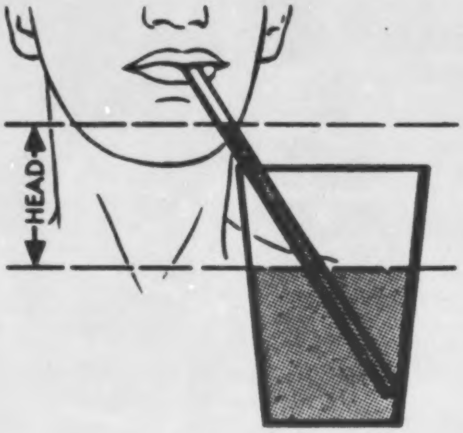

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Figure 2-22.—Partial vacuum.

ratio. An increase in force can be obtained only by a proportional decrease in distance traveled. This is also true if the system is operated in the reverse direction—a distance increase can be obtained, but only at the expense of a force decrease in the same ratio. This leads to the basic statement: Neglecting friction, in any fluid power system (or any other mechanical system for that matter), the input force multiplied by the distance through which it moves, is always exactly equal to the output force multiplied by the distance through which it travels.

Work and Energy

Work is defined as a force moving through some distance, and the amount of work done is the product of the force multiplied by the distance through which it moves. Therefore, when friction is neglected, the work output is always equal to the work input. Energy includes work and, in addition, all forms into which work can be converted or which can be converted into work. Work always involves actual movement, but energy can be at rest and still exist as energy, as long as it is capable of doing work.

Energy can exist in many different forms, but all have one thing in common; they are all interchangeable with each other and with work. Some of the many forms which energy can take and their interchangeability are illustrated by a hydroelectric plant. (See fig. 2-23.) Here, a body of water is held back by a dam. In this case the water represents potential energy, because it is not doing work at the moment, but is capable of doing work if it is released. If an opening is provided, water will rush out in a high velocity jet representing energy of motion or kinetic energy. If this jet is directed against the blades of a water wheel it will push them around, producing a continuous rotary motion. This is work in its true sense because a force is moving through a distance.

The water wheel can, in turn, be connected to an electric generator which converts the work into electricity. This electricity can, in turn, be converted back into work by the use of an electric motor; or it can be converted into light by the use of an electric bulb or into heat in an electric iron. By means of a motor and a pump, the energy can be transformed back into its original form of potential energy existing as a body of water at an elevation. Thus, all of these forms of energy are interchangeable with each other. In actual mechanisms, there is always some loss in the form of heat, which is produced by friction, at every exchange. However, the total energy, useful and wasted, will always add up to the original input energy.

For simplicity, friction was disregarded in the preceding discussions. However, it is well known that there is always some friction in actual machines. It is also known that heat is produced whenever work is accomplished against friction. Therefore, heat is a form of energy because it can be produced from work. Likewise, heat in the form of fire under a boiler can be converted into work through the medium of a steam engine.

Friction represents a loss of efficiency, but this does not mean an annihilation of energy itself. It means only that some of the energy put into the system has been converted into another form which is not useful for the particular problem in hand. The energy is not usable or available, but it still exists as dissipated heat.

In agreement with this fact, any work or energy added to the system must in turn come

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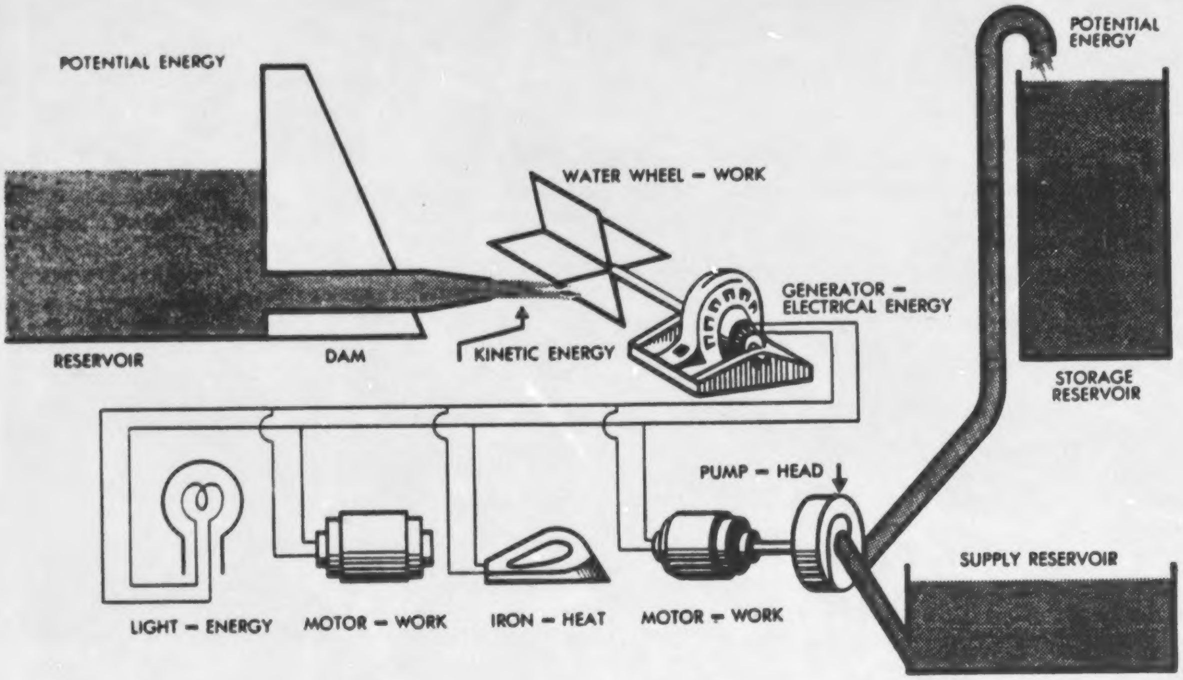

POTENTIAL ENERGY
WATER WHEEL – WORK
POTENTIAL ENERGY
GENERATOR – ELECTRICAL ENERGY
RESERVOIR
DAM
KINETIC ENERGY
STORAGE RESERVOIR
PUMP – HEAD
SUPPLY RESERVOIR
LIGHT – ENERGY
MOTOR – WORK
IRON – HEAT
MOTOR – WORK

FP.23

Figure 2-23.—Potential and kinetic energy.

from somewhere else, for it is not possible to create or destroy energy. All that can be accomplished is to change it from one form into other forms, so as to make it more or less applicable to the purposes at hand. In the case of a hydraulic jack, since there is always some friction both within the liquid and between adjacent parts, the useful work output will not exactly equal the work input, but the difference will always exist somewhere in some other form of energy. In this case, it will appear as heat which must escape from the system somewhere at sometime. In other words, while the usable work output does not equal the input, the total energy output in all forms will always exactly equal the total energy input. This is known as the law of the conservation of energy.

Work and Power

Work and energy are measured in the same units, the foot-pound in the English system and the gram-centimeter in the metric system. Power is the rate of doing work. The same amount of work may be accomplished in two instances but less time is used in one case than in the other. More power is required where less time is used. The unit for measuring power in the English system is the horsepower, which is at the rate of 33,000 foot-pounds per minute or 550 foot-pounds per second. The metric system uses the centimeter-gram per second as its unit of measurement.

FLUID FLOW

In the operation of fluid power systems, there must be a flow of fluid. The amount of flow will vary from system to system. In order to understand fluid power systems in action, it is necessary to become acquainted with some of the elementary characteristics of fluids in motion. Among these are volume and velocity of flow, steady and unsteady flow, streamline and turbulent flow, and, even more important, the force and energy changes that occur in flow and the relations of different kinds of energy to each other in fluid power systems. These characteristics are discussed in the following paragraphs. Additional information concerning fluid flow as it applies to fluidics is presented in chapter 14.

VOLUME AND VELOCITY OF FLOW

The quantity of fluid that passes a given point in a fluid power system in a unit of time is referred to as the volume of flow. Volume of flow can be stated in a number of ways; for example, 100 cubic feet per minute, 100 gallons per minute, 100 gallons per hour, etc. Gallons per minute is the usual method of expressing volume of flow in hydraulic systems, while cubic feet per minute is common in pneumatic systems. The relative pressure of the fluid is usually considered when expressing the volume of flow. This is especially important when considering the volume of flow of gases, since they are compressible. For example, at the same temperature, a cubic foot of gas at 100 psi contains twice as many molecules as a cubic foot of gas at 50 psi.

Velocity of flow means the rate or speed at which the fluid moves forward at a particular point in the system. It too can be variously stated, but the usual method is in feet per second.

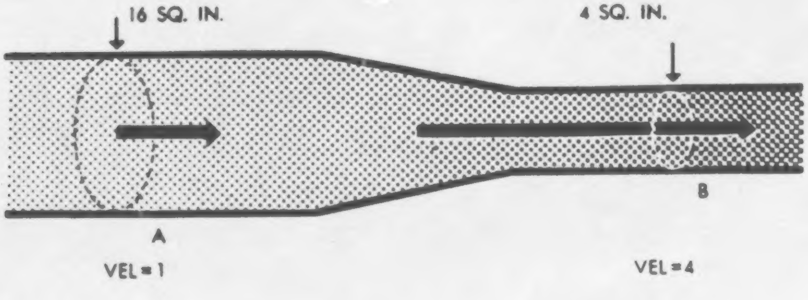
Volume and velocity of flow are often considered together. With other conditions unaltered—that is, with volume of input unchanged—the velocity of flow increases as the cross section or size of the pipe decreases, and the velocity of flow decreases as the cross-sectional area increases. In a stream, velocity of flow is slow at wide parts of the stream and rapid at narrow parts even though the volume of water passing each part of the stream is the same. In figure 2-24, if the cross-sectional area of the pipe is 16 square inches at point (A) and 4 square inches at point (B) the velocity of flow at (B) is four times the velocity at (A).

STEADY AND UNSTEADY FLOW

A fluid may flow as a single continuous stream, or the volume of flow may increase, decrease, or fluctuate from moment to moment. Such changes in volume constitute unsteady flow. For example, when a faucet is first opened, the initial flow is unsteady during the short time that the rate of flow of the water is increasing from the initial zero rate to the full rate of flow. The flow then becomes steady and is maintained if the pressure remains constant. If the pressure changes, the rate of flow once more becomes unsteady until a new balance is reached.

STREAMLINE AND TURBULENT FLOW

At quite low velocities or in tubes of small diameter, flow is streamline, meaning that a given particle of fluid moves straight forward



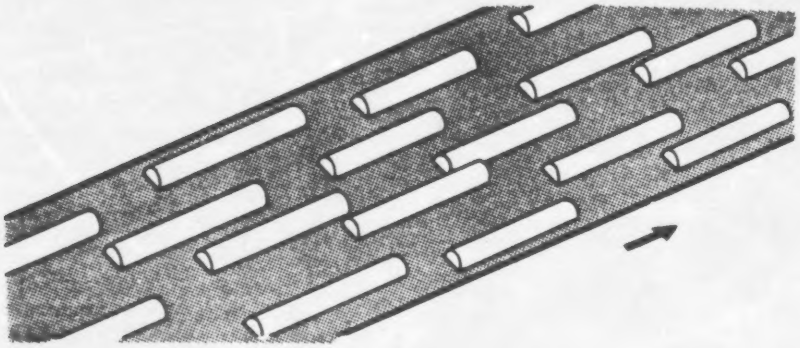
FP.24

Figure 2-24.—Volume and velocity of flow.

without crossing the paths followed by other particles, and without bumping into them. Streamline flow is often referred to as laminar flow, which is defined as a flow situation in which fluid moves in parallel lamina or layers. As an example of streamline flow, consider figure 2-25, which illustrates an open stream flowing at a slow, uniform rate with logs floating on its surface. The logs represent particles of fluid. So long as the stream flows along at a slow, uniform rate, each log floats downstream in its own path, without crossing or bumping into the other.

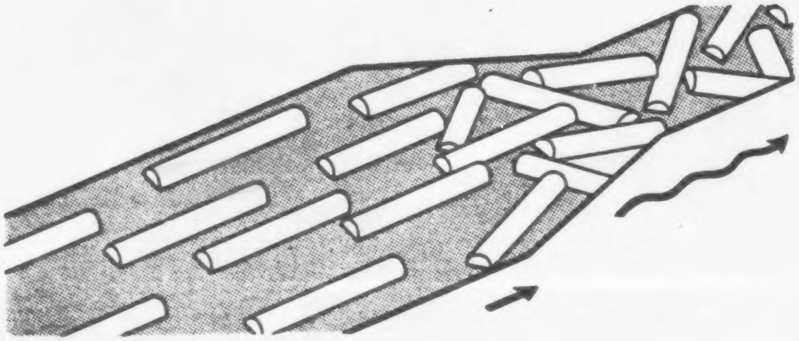
If the stream narrows, however, and the volume of flow remains the same, the velocity of flow increases. If the velocity increases sufficiently, the water becomes turbulent. (See fig. 2-26.) Swirls, eddies, and cross-motions are set up in the water. As this happens, the logs are thrown against each other and against the banks of the stream, and the paths followed by different logs will cross and recross.

Particles of fluid flowing in pipes act in the same manner. The flow is streamline if the fluid flows slowly enough, and remains streamline at greater velocities if the diameter



FP.25

Figure 2-25.—Streamline flow.



FP.26

Figure 2-26.—Turbulent flow.

of the pipe is small. If the velocity of flow or size of pipe is increased sufficiently, the flow becomes turbulent.

One effect of turbulent flow is illustrated in figure 2-27, where the length of the horizontal arrows indicates the relative velocities of flow at different places in the pipe, from the center to the edge, when the flow is streamline and when the flow is turbulent. In both instances the rate of flow varies from the center of the pipe to the edge, but the streamline flow varies more in velocity than turbulent flow. For streamline flow, the average velocity is about one-half the maximum velocity, while for turbulent flow it is about four-fifths. Velocity of flow varies both vertically and horizontally, or from the center of the pipe outward. In both streamline and turbulent flow, the fluid next to the wall of the pipe has no velocity.

While a high velocity of flow will produce turbulence in any pipe, other factors contribute to turbulence. Among these are the roughness of the inside of the pipe, obstructions, and the degree of curvature of bends and the number of bends in the pipe. In setting up or maintaining fluid power systems, care should be taken to eliminate or minimize as many causes of turbulence as possible, since the energy consumed by turbulence is wasted. Limitations as to the degree and number of bends of pipe are discussed chapter 5.

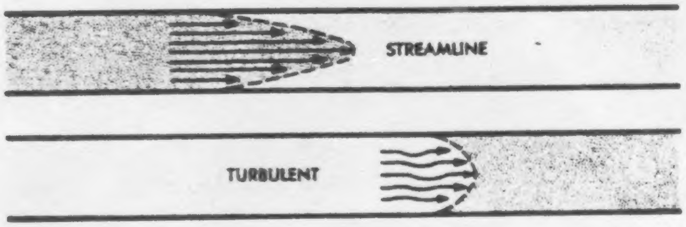
While designers of fluid power equipment do what they can to minimize turbulence, to a very considerable extent it cannot be avoided. For example, in a 4-inch pipe at 68° F, flow becomes turbulent at velocities over approximately 6 inches per second or about 3 inches per second in a 6-inch pipe. These velocities are far below those commonly encountered in fluid power systems, where velocities of 5 feet per second and above are common. In streamline flow, losses due to friction increase directly with velocity, while with turbulent flow these losses increase much more rapidly.

FACTORS INVOLVED IN FLOW

An understanding of the behavior of fluids in motion, or solids for that matter, requires an understanding of the term "inertia." Inertia is the term used by scientists to describe that property possessed by all forms of matter which makes the matter resist being moved if it is at rest, and likewise, resist any change in its rate of motion if it is moving.

The basic statement covering the action of inertia is: "A body at rest tends to remain at rest, and a body in motion tends to continue in motion with the same velocity and in the same direction." This is simply saying what everyone has learned by experience—that one must push an object to start it moving and offer an opposition to stop it again.

A familiar illustration is the effort a pitcher must exert to make a fast pitch and the opposition the catcher must put forth to stop the ball. Similarly, considerable work must be performed by the engine to make an automobile begin to roll; although, after it has attained a certain velocity, it will roll along the road at uniform speed if just enough effort is expended to overcome friction, while brakes are necessary to stop its motion. Inertia also explains the kick or recoil of guns and the tremendous striking force of projectiles.



FP.27

Figure 2-27.—Streamline versus turbulent flow.

Inertia and Force

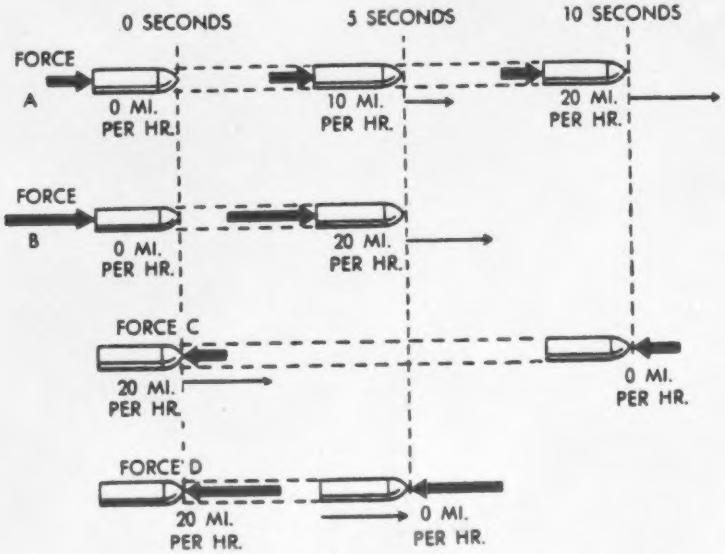
In order to overcome the tendency to resist any change in its state of rest or motion, some force which is not otherwise canceled or unbalanced must act upon the object. Some unbalanced force must be applied whenever fluids are set in motion or increased in velocity; while conversely, forces are made to do work elsewhere whenever fluids in motion are retarded or stopped.

Ignoring friction, if the force (A) in figure 2-28 produces a velocity of 10 miles per hour (mph) when it is applied to a body for 5 seconds, it will produce a velocity of 20 mph when it is applied for 10 seconds. The same result of 20 mph would be obtained if a force (B) equal to twice (A) were applied to the body for 5 seconds. Again ignoring friction, the body would be returned to rest from a velocity of 20 mph if force (C), equal to (A) but acting in the opposite direction, were applied to it for 10 seconds, or if a force (D) equal to twice (C) were applied to it for 5 seconds.

There is a direct relationship between the magnitude of the force exerted and the inertia against which it acts. This force is dependent on two factors—on the mass of the object (which is proportional to its weight), and on the rate at which the velocity of the object is changed. The rule is that the force in pounds required to overcome inertia is equal to the weight of the object, multiplied by the change in velocity measured in feet per second, and divided by 32.2 times the time in seconds required to accomplish the change. Thus, the rate of change in velocity of an object is proportional to the force applied. The number 32.2 appears because it is the conversion factor between weight and mass.

As discussed previously, fluids are always acted upon by the force of gravity, or in other words, by their own weight. Also previously explained, is the fact that fluids are acted upon by atmospheric pressure, or the weight of air over the system, if they are exposed to it—if, that is, the system is not enclosed. The action of specific applied force was also explained and, in addition, it was pointed out that whenever there is movement there is always some friction. Inertia, just described, completes the list of forces which control the action of fluids in motion.

There are five physical factors which can act upon a fluid to affect its behavior. All of the physical actions of fluids in all systems



FP.28

Figure 2-28.—Force and velocity.

are determined by the relationships of these five factors to each other. Summarizing, these five factors are as follows:

1. Gravity, which acts at all times upon all bodies, regardless of other forces.

2. Atmospheric pressure, which acts on any part of a system exposed to the open air.

3. Specific applied forces, which may or may not be present, but which, in any event, are entirely independent of the presence or absence of motion.

4. Inertia, which comes into play whenever there is a change from rest to motion or the opposite, or whenever there is a change in direction or in rate of motion

5. Friction, which is always present whenever there is motion.

Figure 2-29 illustrates a possible relationship of these factors with respect to a particle of fluid (P) in a system. The different forces are shown in terms of head, or in other words, in terms of vertical columns of fluid required to provide the forces. At the particular moment under consideration, a particle of water (P) is being acted upon by an applied force equivalent to a head (A), by atmospheric pressure to a head (B), and by gravity head (C) produced by the weight of the fluid standing over it. The particle possesses sufficient inertia or velocity head to rise to level (P1), since head equivalent to (F) was lost in friction as (P) passed through the system. Since atmospheric pressure (B) acts downward on the system on both sides, what was gained on one side was lost on the other.

If all the pressure acting on (P) to force it through the nozzle could be recovered in the form of elevation head, it would rise to level (Y). If account is taken of the balance in atmospheric pressure, in a frictionless system, (P) would rise to level (X), or precisely as high as the sum of the gravity head and the head equivalent to the applied force.

Kinetic Energy

It was previously pointed out that a force must be applied to an object in order to impart velocity to it or to increase the velocity it already has. Of necessity the force must act

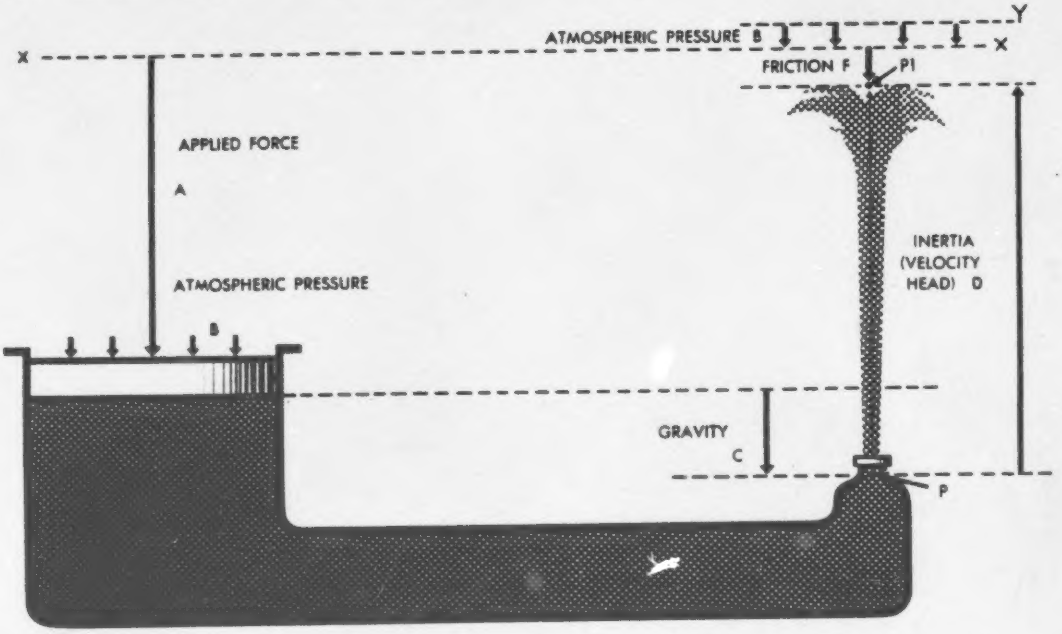


Figure 2-29.—Physical factors governing fluid flow.

while the object is moving over some distance. It was also previously stated that a force acting over a distance is work, and that work and all forms into which it can be changed are classified as energy. Obviously, then, energy is required to give an object velocity. The greater the energy used, the greater the velocity will be.

Likewise, disregarding friction, for an object to be brought to rest or its motion slowed down, a force opposed to its motion must be applied to it. This force also acts over some distance. In this way energy is given up by the object and delivered in some form to whatever opposes its continuous motion. The moving object is therefore a means of receiving energy at one place (where its motion is increased) and delivering it to another point (where it is stopped or retarded). While it is in motion, it is said to contain this energy as energy of motion or kinetic energy.

Since energy can never be destroyed, it follows that if friction is disregarded the energy delivered to stop the object will exactly equal the energy which was required to increase its speed. At all times the amount of kinetic energy possessed by an object depends upon its weight and the velocity at which it is moving.

Thus, in figure 2-30, the force (F) is applied to the body (A), which is at rest. Disregarding friction, after it has moved 1 foot it will possess kinetic energy equivalent to 1. During each succeeding foot of movement it will gain an equal increment of kinetic energy, so long as the force is applied. If it meets a resistance after moving 5 feet, kinetic energy equivalent to 5 is available to do work. Accelerated motion has been a means of receiving energy while force (F) was applied to (A), and of delivering it to do work at the point (A) reached at that time.

The mathematical relationship for kinetic energy is stated in the rule: "Kinetic energy in foot-pounds is equal to the force in pounds which created it, multiplied by the distance through which it was applied, or to the weight of the moving object in pounds, multiplied by the square of its velocity in feet per second, and divided by 64.4."

The relationship between inertia forces, velocity, and kinetic energy can be illustrated by analyzing what happens when a gun fires a projectile against the armor of an enemy ship. (See fig. 2-31.) The explosive force of the powder in the breach pushes the projectile out of the gun, giving it a high velocity. Because of its inertia the projectile offers opposition to this sudden velocity and a reaction is set up which pushes the gun backward (kick or recoil). The force of the explosion acts on the projectile throughout its movement in the gun. This is force acting through a distance producing work. This work appears as kinetic energy in the speeding projectile. The resistance of the air produces friction, which uses some of the energy and slows down the projectile. Eventually, however, the projectile hits its target and because of the inertia tries to continue moving. The target, being relatively stationary, tends to remain stationary because of its inertia. The result is that a tremendous force is set up which either leads to the penetration of the armor or the shattering of the projectile. The projectile is simply a means of transferring energy, in this instance for destructive purpose, from the gun to the enemy ship. This energy is transmitted in the form of energy of motion or kinetic energy.

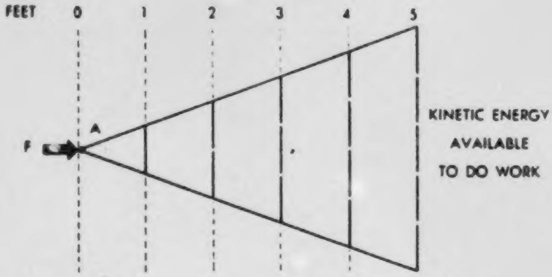


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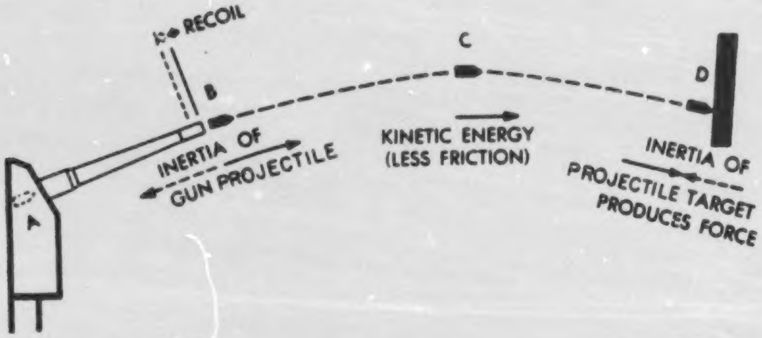
Figure 2-30.—Kinetic energy.

Referring to figure 2-31, the projectile is shown in four different positions: at (A) where it is at rest in the gun, just before firing; at (B), a short distance beyond the muzzle of the gun, when its kinetic energy is at the maximum; at (C), midway in its flight, where friction has used up a portion of its original kinetic energy; and at (D), at the moment of impact, where its kinetic energy is suddenly transformed into work by its inertia and the opposed inertia offered by the target. Energy



FP.31

Figure 2-31.—Relationship of inertia, velocity, and kinetic energy.

imparted to the projectile at (A) has been transformed in the form of kinetic energy to do work at (D).

In this diagram no effort has been made to exhibit the magnitude of the force of gravity acting on the projectile. It enters, of course, into the path the projectile takes. This situation differs from that shown in figure 2-30 in which the propelling force was continuously applied throughout the period covered by the diagram, whereas in figure 2-31, the force was applied while the projectile was moving from (A) to (B).

A similar action takes place in a fluid power system in which the fluid takes the place of the projectile. For example, the pump in a hydraulic system imparts energy to the fluid which overcomes the inertia of the fluid at rest and causes it to flow through the lines. The fluid flows against some type of actuator which is at rest. The fluid tends to continue flowing, overcomes the inertia of the actuator, and moves the actuator to do work. Friction uses up a portion of the energy as the fluid flows through the lines and components.

RELATIONSHIP OF FORCE, PRESSURE, AND HEAD

In dealing with fluids, forces are usually considered in relation to the areas over which they are applied. As previously discussed, a force acting over a unit area is a pressure, and pressure can alternately be stated in psi or in terms of head, which is the vertical height of the column of fluid whose weight would produce that pressure.

In most of the applications of fluid power in the Navy, applied forces greatly outweigh all other forces, and in most systems the fluid is entirely confined. Under these circumstances it is customary to think of the forces involved in terms of pressures. Since the term head is encountered frequently in the study of fluid power, it is necessary to understand what it means and how it is related to pressure and force.

All five of the factors which control the actions of fluids can, of course, be expressed either as force, or in terms alternately of equivalent pressures or head. In each situation, however, the different factors are commonly referred to in the same terms, since on this common basis they can be added and subtracted to study their relationship to each other.

At this point some terms in general use should be reviewed. Gravity head, when it is of sufficent importance to be considered, is sometimes referred to as head. The effect of atmospheric pressure is referred to simply as atmospheric pressure. (Atmospheric pressure is frequently and improperly referred to as suction.) Inertia effect, because it is always directly related to velocity, is usually called velocity head, and friction, because it represents a loss of pressure or head, is usually referred to as friction head.

STATIC AND DYNAMIC FACTORS

The first three factors—gravity, applied force, and atmospheric pressure—apply equally to fluids at rest or in motion, while the latter two—inertia and friction—apply only to fluids in motion. The first three are the static factors and the latter two the dynamic factors. The mathematical sum of the first three—gravity, applied force, and atmospheric pressure—is the static pressure obtained at any one point in a fluid at any given time. Static pressure exists in addition to any dynamic factors which may also be present at the same point and time.

Remember, Pascal's law states that a pressure set up in a fluid acts equally in all directions and at right angles to the containing surfaces. This covers the situation only for fluids at rest, or practically at rest. It is true only for the factors making up static head. Obviously, when velocity becomes a factor it must have a direction, and, as previously explained, the force related to the velocity must also have a direction, so that Pascal's law alone does not apply to the dynamic factors of fluid power.

The dynamic factors of inertia and friction are related to the static factors. Velocity head and friction head are obtained at the expense of static head. However, a portion of the velocity head can always be reconverted to static head. Force, which can be produced by pressure or head when dealing with fluids, is necessary to start a body moving if it is at rest, and is present in some form when the motion of the body is arrested. Therefore, whenever, a fluid is given velocity, some part of its original static head is used to impart this velocity, which then exists as velocity head.

BERNOULLI'S PRINCIPLE

Consider the system illustrated in figure 2-32. Chamber (A) is under pressure and is connected by a tube to chamber (B), which is also under pressure. The pressure in chamber (A) is static pressure of 100 psi. The pressure at some point (X) along the connecting tube consists of a velocity pressure of 10 psi exerted in a direction parallel to the line of flow, plus the unused static pressure of 90 psi, which still obeys Pascal's law and operates equally in all directions. As the fluid enters chamber (B) it is slowed down, and, in so doing, its velocity head is changed back to pressure head. The force required to absorb its inertia equals the force required to start the fluid moving originally, so that the static pressure in chamber (B) is again equal to that in chamber (A), although it was lower at an intermediate point.

This situation (fig. 2-32) disregards friction, and would therefore, not be encountered in actual practice. Force or head is also required to overcome friction, but, unlike inertia effect, this force cannot be recovered again, although the energy represented still exists somewhere as heat. Therefore, in an actual system the pressure in chamber (B) would be less than in chamber (A) by the amount of pressure used in overcoming friction along the way.

At all points in a system, therefore, the static pressure is always the original static

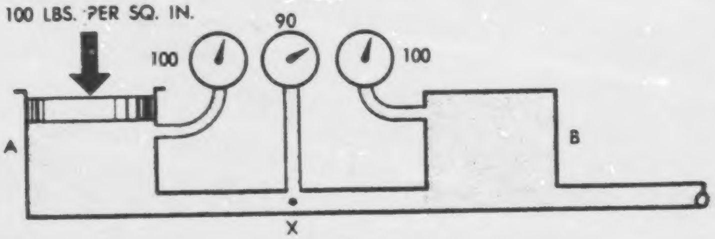


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Figure 2-32.—Relation of static and dynamic factors—Bernoulli's principle.

pressure less any velocity head at the point in question, and less the friction head consumed in reaching that point. Since both velocity head and friction represent energy which came from the original static head, and since energy, cannot be destroyed, the sum of the static head velocity head, and friction at any point in the system must add up to the original static head. This is known as Bernoulli's principle, which states: "For the horizontal flow of fluid through a tube, the sum of the pressure and the kinetic energy per unit volume of the fluid is constant." This principle governs the relations of the static and dynamic factors concerning fluids, while Pascal's law states the manner in which the static factors behave when taken by themselves.

MINIMIZING FRICTION

As mentioned previously, fluid power equipment is designed to reduce friction to the lowest possible level. Volume and velocity of flow are made the subject of careful study. The proper fluid for the system is chosen. Clean, smooth pipe of the best dimensions for the particular conditions is used, and it is installed along as direct a route as possible. Sharp bends and sudden changes in cross-sectional areas are avoided. Valves, gages, and other components are designed so as to interrupt flow as little as possible. Careful thought is given to the size and shape of the openings. The systems are designed so they can be kept clean inside and variations from normal operation can easily be detected and remedied.

CHAPTER 3

HYDRAULIC AND PNEUMATIC FLUIDS

During the design of equipment that requires fluid power, many factors must be considered in the selection of the type of system to be used—hydraulic, pneumatic, or a combination of the two. Some of the factors that must be considered are as follows: Required speed and accuracy of operation, surrounding atmospheric conditions, economic conditions, availability of replacement fluid, required pressure level, operating temperature range, contamination possibilities, cost of transmission lines, limitations of the equipment, lubricity, safety to the operators, and expected service life of the equipment.

After the type of system has been selected, many of these same factors must be considered in selecting the fluid for the system. The first part of this chapter is devoted to hydraulic liquids. Included in this part are sections on the properties and characteristics desired of hydraulic liquids, the basic types of hydraulic liquids, and the types and control of contamination. The last part of the chapter covers similar information concerning the gases used in pneumatic systems.

HYDRAULIC LIQUIDS

Liquids are used in hydraulic systems primarily to transmit and distribute forces to the various units to be actuated. As pointed out in chapter 2, liquids are able to do this because they are almost incompressible. Pascal's law states that a force applied on any area of an enclosed liquid is transmitted equally and undiminished to all equal areas throughout the enclosure. Thus, if a number of passages exist in a system, pressure can be distributed through all of them by means of a liquid.

Commercial manufactures of hydraulic devices usually specify the type of liquid best suited for use with their equipment. Their recommendations are based on the working conditions, the service required, temperatures expected both inside and outside the system, pressures the liquid must withstand, the possibilities of corrosion, etc. In addition to the manufacturer's recommendations, the proper specifications for liquids used in Navy hydraulic systems are determined by the various systems commands on the basis of experiments, tests, and trials. For example, many experiments and tests were made in the search for hydraulic liquids adapted to both the subzero Arctic climate and high temperattures of the Tropics.

PROPERTIES

If fluidity (the physical property of a substance that enables it to flow) and incompressibility were the only qualities required, any liquid not too thick might be used in a hydraulic system. However, a satisfactory liquid for a particular installation must possess a number of other properties. Some of the properties and characteristics that must be considered when selecting a satisfactory liquid for a particular system are discussed in the following paragraphs.

Viscosity

One of the most important properties of a liquid to be used in hydraulic system is its viscosity. Viscosity is the internal resistance of a fluid which tends to prevent it from flowing. A liquid, such as gasoline, which flows easily has a low viscosity; and a liquid, such as tar, which flows slowly has a high viscosity. The viscosity of a liquid is affected by changes in temperatures. As the temperature of a liquid increases, its viscosity (resistance to flow) decreases. That is, a liquid flows more easily when hot than when cold. Also, the viscosity of a liquid will increase as the pressure increases.

A satisfactory liquid for a given hydraulic system must have enough body to give a good seal at pumps, motors, valves, etc. These components depend upon close fits for creating and maintaining pressure. Internal leakage through these clearances results in loss of pressure, instantaneous control, and pump efficiency. These leakage losses are greater with lighter liquids (low viscosity). A liquid that is too thin will also lead to rapid wearing of moving parts, or of parts having heavy loads. On the other hand, if the viscosity of the liquid is too high the internal friction of the liquid will increase which in turn will increase the flow resistance through clearances of closely fitted parts, lines and passages. This results in pressure drops throughout the system, sluggish operation of the equipment, and an increase in power consumption.

MEASUREMENT OF VISCOSITY.—The viscosity of a liquid is measured with an instrument called a viscosimeter or viscometer. There are several types, but the instrument most commonly used by American engineers is the Saybolt Universal Viscosimeter. (See fig. 3-1.) This instrument measures the number of seconds it takes for a fixed quantity of liquid (60 cubic centimeters) to flow through a small orifice of standard length and diameter at a specific temperature. The time of flow is taken in seconds, and the viscosity reading is expressed as Second, Saybolt Universal (SSU). For example, a certain liquid might have a viscosity of 80 SSU at 130° F.

The Saybolt Viscosimeter consists of a container for the liquid surrounded by a bath heated by heating coils to bring the liquid to the temperature at which the viscosity is to be measured. There is a standard viscosimeter orifice located in the bottom of the container. Passage through the orifice is blocked with a cork. The container is filled to a marked level with the liquid to be tested and a small container marked at the 60-cubic centimeter (cc) level is placed under the orifice. When the liquid is at the desired temperature, the cork is removed. The number of seconds required for the liquid to reach the 60-cc level gives the SSU reading.

VISCOSITY INDEX.—One of the properties of an ideal hydraulic liquid would be that of retaining the same viscosity under all temperature and pressure conditions to which it is subjected. Many liquids, particularly petroleum base oils, do not have this characteristic. As the temperature increases the oil becomes thinner—the viscosity decreases; as the temperature decreases, the oil thickens—the viscosity increases. The variation is greater for some liquids than for others. Pennsylvania crude oils (paraffinic) vary comparatively little in viscosity with changes in temperature; while with Gulf Coast crude (naphthenic or asphaltic), the variation is considerably greater.

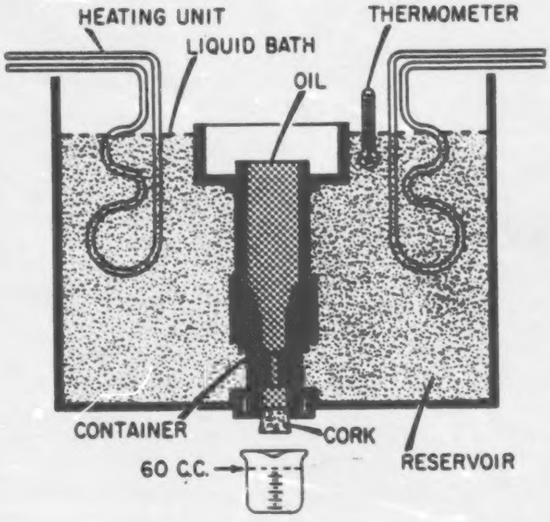

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Figure 3-1.—Saybolt Viscosimeter.

In order to obtain a numerical indication of the degree to which viscosity changes with change in temperature, these two oils (paraffinic and naphthenic) are taken as the basis for a scale. The change in viscosity of a specific paraffinic oil at temperatures between 100° and 210° F is assigned a viscosity index (V.I.) value of 100, while the change in viscosity of a specific naphthenic oil over the same temperature range is assigned a value of 0. Other liquids are then assigned a viscosity index in terms of the degree to which their viscosity changes over this temperature range, as compared to the standard oils.

The greater the variation in viscosity with changes in temperature, the lower the V.I. The V.I. figures may range above 100 or below zero, if the liquids being measured vary less or greater in viscosity than the standard oils. For example, a liquid with a viscosity index of -10 would indicate a variation in viscosity over the standard temperature range to a greater degree than naphthenic oils; while an oil with a viscosity index of 120 would show less change in viscosity with changes in temperature than paraffinic oils.

Since naval hydraulic systems must operate satisfactorily under wide temperature extremes, from the Arctic regions to the Tropics and from below sea level to many miles into space, the liquids used should have as high a viscosity index as possible, consistant with the other properties the liquid must possess. The viscosity index of a liquid is often increased through the use of chemical additives.

Lubricating Power

If motion takes place between surfaces in contact, friction tends to oppose the motion. When pressure forces the liquid of a hydraulic system between the surfaces of moving parts, the liquid spreads out in a thin film which enables the parts to move more freely. Different liquids, including oils vary greatly not only in their lubricating ability, but also in film strength which is the capability of a liquid to resist being wiped or squeezed out from between the surfaces when spread out in an extremely thin layer. A liquid will no longer lubricate if the film breaks down, since the motion of part against part wipes the metal clean of liquid.

Lubricating power varies with temperature changes; therefore, the climatic and working conditions must enter into the determination of the lubricating qualities of a liquid. Unlike viscosity, which is a physical property, the lubricating and film strength of a liquid is directly related to its chemical nature. Lubricating qualities and film strength can be improved by the addition of certain chemical agents.

Chemical Stability

Chemical stability is another property which is exceedingly important in the selection of a hydraulic liquid. It is defined as the liquid's ability to resist oxidation and deterioration for long periods. All liquids tend to undergo unfavorable changes under severe operating conditions. This is the case, for example, when a system operates for a considerable period of time at high temperatures.

Excessive temperature, especially extremely high temperatures, have a great effect on the life of a liquid. It should be noted that the temperature of the liquid in the reservoir of an operating hydraulic system does not always represent a true state of the operating conditions throughout the system. Localized hot spots occur on bearings, gear teeth, or at other points where the liquid under pressure is forced through small orifices. Continuous passage of the liquid through these points may produce local temperatures high enough to carbonize or sludge the liquid, yet the liquid in the reservoir may not indicate an excessively high temperature.

Liquids with a high viscosity have a greater resistance to heat than light or low viscosity liquids which have been derived from the same source. The average hydraulic liquid has a relatively low viscosity. Fortunately, there is a wide choice of liquids available for use in the viscosity range required of hydraulic liquids.

Liquids may break down if exposed to air, water, salt, or other impurities, especially if they are in constant motion or subjected to heat. Some metals, such as zinc, lead, brass, and copper, have an undersirable chemical reaction on certain liquids.

These chemical processes result in the formation of sludge, gums, and carbon or other deposits which clog openings, cause valves and pistons to stick or leak, and give poor lubrication to moving parts. As soon as a small amount of sludge or other deposits are formed, the rate of formation generally increases more rapidly. As they are formed, certain changes in the physical and chemical properties of the liquid take place. The liquid usually becomes darker, higher in viscosity, and acids are formed.

The extent to which changes occur in different liquids depends on the type of liquid, type of refining, and whether it has been treated to provide further resistance to oxidation. The stability of liquids can be improved by the addition of oxidation inhibitors. Laboratory test must be conducted to select the type and quantity of the inhibitor most effective against oxidation of a particular liquid. However, inhibitors selected to improve the stability of a liquid must also be compatible with the other required properties of the liquid.

Freedom from Acidity

An ideal hydraulic liquid should be free from acids which cause corrosion of the metals in the system. Most liquids cannot be expected to remain completely noncorrosive under severe operating conditions. The degree of acidity of a liquid, when new, may be satisfactory; but after use, the liquid may tend to develop corrosive tendencies as it begins to deteriorate. The liqquid must be carefully processed with the specific aim of inhibiting harmful acid formation which would attack metal surfaces in the system.

Many systems are idle for long periods after operating at high temperatures. This permits moisture to be condensed in the system, resulting in rust formation.

Certain corrosion-and rust-preventive additives are added to hydraulic liquids. Some of these additives are effective only for a limited period. Therefore, the best procedure is to use the liquid specified for the system, and to protect the liquid and the system as much as possible from contamination by foreign matter, from abnormal temperatures, and misuse.

Flashpoint

Flashpoint is the temperature at which a liquid gives off vapor in sufficient quantity to ignite momentarily or flash when a flame is applied. A high flashpoint is desirable for hydraulic liquids because it provides good resistance to combustion and a low degree of evaporation at normal temperatures.

Fire Point

Fire point is the temperature at which a substance gives off vapor in sufficient quantity to ignite and continue to burn when exposed to a spark or flame. Like flashpoint, a high fire point is required of desirable hydraulic liquids.

Minimum Toxicity

Toxicity is defined as the quality, state, or degree of being toxic or poisonous. Some liquids contain chemicals that are a serious toxic hazard. These toxic or poisonous chemicals may enter the body through inhalation, by absorption through the skin, through the eyes, or through the mouth. The result is sickness and in many cases death. Manufactures of hydraulic liquids strive to produce suitable liquids that contain no toxic chemicals and, as a result, most hydraulic liquids are free of harmful chemicals. Some fire-resistant liquids are toxic, and suitable protection and care in handling must be provided. Containers for toxic liquids must be properly labeled.

NOTE: MIL-STD-755A establishes a uniform design for symbols to warn users of potential hazards involved with the use of materials in containers. The toxic symbol consists of a brown edged square inside of which is a brown circular patch on a white background. A skull and the following lettering appears in white on the brown patch: DANGER, TOXIC, CONTAINS (name of substance) AVOID INHALING, SWALLOWING, OR CONTACT WITH THE SKIN. Additional information concerning the identification of compressed-gas cylinders and pipelines containing hazardous substance is contained in MIL-STD-101A and MIL-STD-1247B.

TYPES OF HYDRAULIC LIQUIDS

Many different liquids have been tested for use in hydraulic systems. The liquids that are presently in use include mineral oil, vegetable oil, water, phosphate esters, ethylene glycol compounds, and oil in water. Hydraulic liquids are usually classified according to their type of base. The three most common types of hydraulic liquids are water base, petroleum base, and synthetic base.

Water Base Liquids

Water was used as a fluid medium in the first hydraulic systems. It is still suitable for certain large commercial hydraulic installations that require high pressure and low operating speeds, but it does not meet all the requirements for general hydraulic equipment use. As a hydraulic liquid, water presents many problems. It is limited to temperatures above freezing and below boiling points. It promotes corrosion and rusting of metal parts and provides no lubrication of moving parts. In addition, the hazard of foreign matter in the water itself can cause an abrasive action on the smooth surfaces of system components. All of these act as factors detrimental to the operating efficiency and long service life of the equipment.

One of the major advantages of water is its fire resistant qualities. When water is used as

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a hydraulic liquid, it is usually combined with certain oils, ethylene glycol, and other substances. When combined with oil, the combination is relatively fire resistant. However, high temperatures may cause the water to evaporate and then the oil might burn. Other combinations can eliminate ignition problems but may have mechanical or economic limitations. During the early 1950's, the Navy used Hydrolube, a mixture of water and polyethylene glycol (antifreeze compound) in approximately 80 percent of their aircraft. This liquid contained 35 to 40 percent water mixed with polyethylene glycol, rust inhibitors, thickeners, and lubricating agents. After a few years of use, problems were encountered with thin film corrosion on the hydraulic system components, resulting in the Navy discontinuing its use in aircraft hydraulic systems. Similar water base liquids are used by the Navy in the catapult systems on some aircraft carriers. This was approved following explosions attributed to petroleum base liquids.

Petroleum Base Liquids

One of the first oils used as a hydraulic liquid was a petroleum base automotive brake fluid. At that time natural rubber was used in the construction of packings and gaskets. Since natural rubber is not compatible with petroleum base liquids, the use of this type liquid as a hydraulic medium was limited. As a result, a vegetable base oil containing 50 percent castor oil and 50 percent alcohol was used in some applications. This solved the problem with packings and gaskets, as natural rubber is compatible with vegatable base oils. However, this liquid was unsatisfactory due to oxidation of the castor oil and, since liquid is an excellent conductor of electricity, resulted in a high degree of electrolysis (the chemical disintegration of a substance accomplished by an electric current passing through it). In addition, vegetable oils tend to break down under extreme temperature changes.

During the middle 1930's, a light petroleum base oil was developed and, when used with asbestos seals, proved quite successful. By the late 1930's, advancement in packing materials, such as synthetic rubber seals, permitted extensive use of petroleum base liquids in hydraulic systems. As a result, a pertoleum base oil was developed about 1940 that proved very satisfactory and, with certain refinements, is in use today. This liquid was improved through the use of a number of additives, such as oxidation and corrosion inhibitors, viscosity index improvers, pour depressants, etc. These additives not only permit liquid operation at greater temperature extremes, but add to their lubricating qualities and life characteristics.

Petroleum base liquids are the most widely used media for hydraulic systems. Certain petroleum base oils are used in a number of different applications. For example, MIL-H-5606B is the specification number of the petroleum base oil presently used in most Navy aircraft hydraulic systems. Another example is MIL-F-17111 which is the specification number of the petroleum base oil generally approved for ordnance equipment, except guided missiles. Many special petroleum base oils are required for special applications.

Synthetic Base Liquids

Petroleum base oils contain most of the desired properties required of a hydraulic liquid. However, they are flammable under normal conditions and can become explosively dangerous when subjected to high pressures and a source of flame or high temperatures. Water base liquids are relatively fire resistant, but do not have the high lubricity of petroleum base oils. Some water base liquids cause corrosion of components in the hydraulic system.

In recent years, nonflammable synthetic liquids have been developed for use in hydraulic systems where fire hazards exist. A synthetic material is a complex chemical compound that has been artifically formed by the combining of two or more simpler compounds or elements. Some of the synthetic liquids currently used as a hydraulic medium are chemically described as phosphate esters, chlorinated biphenyls, or blends of each. Certain synthetic liquids have been found to chemically attack packings used in hydraulic systems; therefore, special packings are normally required when these fluids are used.

CONTAMINATION

Experience has shown that trouble in a hydraulic system is inevitable whenever the liquid is allowed to become contaminated. In fact, most manufacturers and users agree that a large percentage of the malfunctions in hydraulic systems may be traced to some type of contaminant in the hydraulic fluid. The nature of the trouble—whether a simple malfunction or the complete destruction of a component—depends to some extent on the type of contaminant.

Classes of Contamination

There are many different types of contaminants which are harmful to hydraulic liquids. These contaminants are divided into two general classes and can be distinguished as follows:

1. Abrasives, including such particles as core sand, weld spatter, machining chips, and rust.
2. Nonabrasives, including those resulting from liquid oxidation, and soft particles worn or shredded from seals and other organic components.

The mechanics of the destructive action by abrasive contaminants is clear. When the size of the particles circulating in the hydraulic system is greater than the clearance between moving parts, the clearance openings act as filters and retain such particles. Hydraulic pressure then embeds these particles into the softer materials, and the reciprocating or rotating motion of component parts develop scratches on finely finished surfaces. Such scratches result in internal component leakage and decreased efficiency.

Liquid-oxidation products, usually called sludge, have no abrasive properties. Nevertheless, sludge may prevent proper functioning of a hydraulic system by clogging valves, orifices, and filters. Frequent changing of hydraulic system liquid is not a satisfactory solution to the contamination problem. Abrasive particles contained in the system are not usually flushed out, and new particles are continually created as friction products. Furthermore, even a small amount of sludge acts as an effective catalyst to speed up oxidation of the fresh liquid. (A catalyst is a substance which, when added to another substance, speeds up or slows down chemical reaction, but is itself unchanged at the end of the reaction.)

Origin of Contaminants

The origin of contaminants in hydraulic systems can be traced to four major areas as follows:

1. Particles originally contained in the system. These particles originate during the fabrication and storage of system components. Weld spatter and slag may remain in welded system components, especially in reservoirs and pipe assemblies. The presence is minimized by proper design. For example, seam-welded overlapping joints are preferred, and arc welding of open sections is usually avoided. Hidden passages in valve bodies, inaccessible to sand blasting or other methods of cleaning, are the main source of introduction of core sand. Even the most carefully designed and cleaned casting will almost invariably free some sand particles under the action of hydraulic pressure. Rubber hose assemblies always contain some loose particles. Most of these particles can be removed by flushing the hose before installation; however, some particles withstand cleaning and are freed later by the action of hydraulic pressure.

Particles of lint from cleaning rags can cause abrasive damage in hydraulic systems, especially to closely fitted moving parts. In addition, lint in a hydraulic system packs easily into clearances between packings and contacting surfaces, leading to component leakage and decreased efficiency. Lint also helps clog filters prematurely. Rust or corrosion initially present in a hydraulic system can usually be traced to improper storage of materials and component parts. Particles can range in size from large flakes to abrasives of microscopic dimensions. Proper preservation of stored parts is helpful in eliminating corrosion.

2. Particles introduced from outside sources. Particles can be introduced into hydraulic systems at points where either the liquid or certain working parts of the system (e.g., piston rods) are at least in temporary contact with the atmosphere. The most common danger areas are at the refill and breather openings, at cylinder rod packings, and at open lines where components are removed for repair or replacement. Contamination arising from carelessness during servicing operations is minimized by the use of filters in the system fill lines and finger strainers in the filler adapter of hydraulic reservoirs. Hydraulic cylinder piston rods incorporate wiper rings and dust seals to prevent the dust that settles on the piston rod during its outward stroke from entering the system when the piston rod retracts. Caps and plug are available and should be used to seal off the open lines

during the time a component is removed for repair or replacement.

3. Particles created within the system during operation. Contaminants created during system operation are of two general types—mechanical and chemical. Particles of a mechanical nature are formed by wearing of parts in frictional contact, such as pumps, cylinders, and packing gland components. These wear particles can vary from large chunks of packings down to steel shavings of microscopic dimensions which are beyond the retention potential of system filters.

The major source of chemical contaminants in hydraulic liquid is oxidation. These contaminants are formed under high pressure and temperatures, and are promoted by the chemical action of water and air and of metals like copper and iron oxides. Liquid-oxidation products appear initially as organic acids, asphaltines, gums, and varnishes—sometimes combined with dust particles as sludge. Liquid soluble oxidation products tend to increase liquid viscosity, while insoluble types separate and form sediments, especially on colder elements such as heat exchanger coils.

Liquid containing antioxidants have little tendency to form gums and sludge under normal operating conditions. However, as the temperature increases, resistance to oxidation diminishes. Hydraulic liquids which have been subjected to excessively high temperatures (above 250° F for most liquids) will break down in substance, leaving minute particles of asphaltines suspended in the liquids. The liquid changes to brown in color and is referred to as decomposed liquid. This explains the importance of keeping the hydraulic liquid temperature below specific levels.

The second contaminant producing chemical action in hydraulic liquids is one which permits these liquids to establish a tendency to react with certain types of rubber. This reaction causes structural changes in the rubber, turning it brittle, and finally causing its complete disintegration. For this reason, the compatibility of system liquid with seals and hose material is a very important factor.

4. Particles introduced by foreign liquids. One of the most common foreign-fluid contaminants is water, especially in hydraulic systems which require petroleum base liquids. Water, which enters even the most carefully designed systems by condensation of atmospheric moisture, normally settles to the bottom of the reservoir. Oil movement in the reservoir disperses the water into fine droplets, and agitation of the liquid in the pump and in high speed passages forms an oil-water-air emulsion. Such emulsion normally separates out during the rest period in the system reservoir; but when fine dust and corrosion particles are present, the emulsion is chemically changed by high pressures into sludge. The damaging action of sludge explains the need for effective filtration, as well as the need for water separation qualities in hydraulic liquids.

Contamination Control

Filters (discussed in chapter 7) provides adequate control of the contamination problem during all normal hydraulic system operations. Control of the size and amount of contamination entering the system from any other source must be the responsibility of the personnel who service and maintain the equipment. Therefore, precaution must be taken to insure that contamination is held to a minimum during service and maintenance. Should the system become excessively contaminated, the filter element should be removed and cleaned or replaced.

As an aid to exercising contamination control, the following maintenance and servioing procedures should be adhered to at all times:

1. Maintain all tools and the work area (work-benches and test equipment) in a clean, dirt-free condition.

2. A suitable container should always be provided to receive the hydraulic liquid which is spilled during component removal or disassembly procedures.

NOTE: The reuse of drained hydraulic liquid is prohibited in some hydraulic systems; for example, aircraft hydraulic systems. In some large capacity systems the reuse of fluid is permitted. When liquid is drained from the latter systems, it must be stored in a clean and suitable container. This liquid must be strained and/or filtered as it is returned to the system reservoir.

3. Before disconnecting hydraulic lines or fittings, clean the affected area with an approved drycleaning solvent.

4. All hydraulic lines and fittings should be capped or plugged immediately after disconnecting.

5. Before assembly of any hydraulic components, wash all parts with an approved drycleaning solvent.

6. After cleaning parts in drycleaning solvent, dry the parts thoroughly and lubricate with the recommended preservative or hydraulic liquid before assembly.

NOTE: Use only clean, lint-free cloths to wipe or dry component parts.

7. All packings and gaskets should be replaced during the assembly procedures.

8. All parts should be connected with care to avoid stripping metal slivers from threaded areas. All fittings and lines should be installed and torqued in accordance with applicable technical instructions.

9. All hydraulic servicing equipment should be kept clean and in good operating condition.

Contamination Checks

Whenever it is suspected that a hydraulic system has become excessively contaminated, or the system has been operated at temperatures in excess of the specified maximum, a check of the system should be made. The filters in most hydraulic systems are designed to remove most foreign particles that are visible to the naked eye. However, hydraulic liquid which appears clean to the naked eye may be contaminated to the point that it is unfit for use.

Thus, visual inspection of the hydraulic liquid does not determine the total amount of contamination in the system. Large particles of impurities in the hydraulic system are indications that one or more components in the system are being subjected to excessive wear. Isolating the defective component requires a systematic process of elimination. Liquid returned to the reservoir may contain impurities from any part of the system. In order to determine which component is defective, liquid samples should be taken from the reservoir and various other locations in the system.

FLUID SAMPLING.—Liquid samples should be taken in accordance with the instructions provided in applicable technical publications for the particular system and the contamination test kit. Some hydraulic systems are provided with permanently installed bleed valves for taking liquid samples; while on other systems, lines must be disconnected to provide a place to take a sample. In either case, while the liquid is being taken, a small amount of pressure should be applied to the system. This insures that the liquid will flow out of the sampling point and thus prevent dirt and other foreign matter from entering the hydraulic system. Hypodermic syringes are provided with some contamination test kits for the purpose of taking samples.

CONTAMINATION TESTING.—Various procedures are recommended to determine the contaminant level in hydraulic liquids. The filter patch test provides a reasonable idea of the condition of the fluid. This test consists basically of filtration of a sample of hydraulic system liquid through a special filter paper. This filter paper darkens in degree in relation to the amount of contamination present in the sample, and is compared to a series of standardized filter discs which, by degree of darkening, indicates the various contamination levels. The equipment provided with one type of contamination test kit is illustrated in figure 3-2.

When using this liquid contamination test kit, the liquid samples should be poured through the filter disc (shown in figure 3-2), and the test filter patches should be compared with the test patches supplied with the test kit. A microscope is provided with the more expensive test kits for the purpose of making this comparison. Figure 3-3 shows test patches similar to those supplied with the testing kit.

To check liquid for decomposition, pour new hydraulic liquid into a sample bottle of the same size and color as the bottle containing the liquid to be checked. Visually compare the color of the two liquids. Liquid which is decomposed will be darker in color.

At the same time the contamination check is made, it may be necessary to make a chemical analysis of the liquid. This analysis consists of a viscosity check, a moisture check, and a flashpoint check. However, since special equipment is required for these checks, the liquid samples must be sent to a laboratory, where a technician will perform the test.

System Flushing

Whenever a contamination check indicates impurities in the system or indicates decomposition of the hydraulic liquid, the hydraulic system must be flushed.

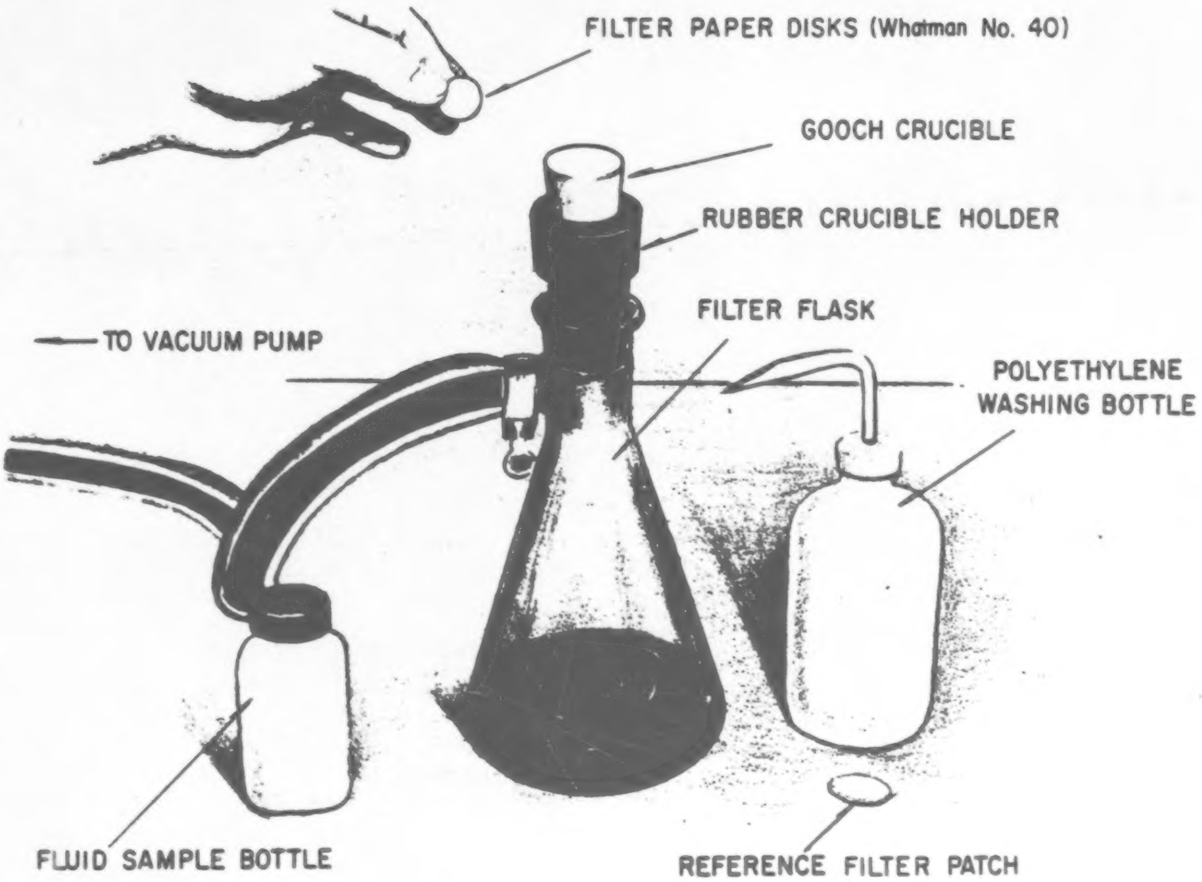
FILTER PAPER DISKS (Whatman No. 40)
GOOCH CRUCIBLE
RUBBER CRUCIBLE HOLDER
FILTER FLASK
TO VACUUM PUMP
POLYETHYLENE WASHING BOTTLE
FLUID SAMPLE BOTTLE
REFERENCE FILTER PATCH

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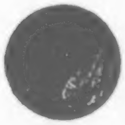
Figure 3-2.—Liquid contamination test kit.

NOTE: The presence of foreign particles in the hydraulic system indicates a possible component malfunction, which should be corrected prior to flushing the system.

A hydraulic system in which the liquid is contaminated should be flushed in accordance with current applicable technical instructions. Flushing procedures are normally recommended by the manufacturer and approved by the Navy. The procedure varies with different hydraulic systems. The following procedures for flushing hydraulic power-transmission systems used with naval ordance are covered in NavOrd OD 3000, Lubrication of Ordance Equipment.

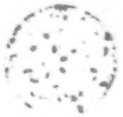
Drain out as much of the contaminated liquid as possible. Drain valves are provided in some systems for this purpose; while on other systems, lines and fittings must be disconnected at the low points of the system to remove any trapped fluid in the lines and components. Close all the connections and fill the system with the applicable flushing medium. Any of the hydraulic liquids approved for use in power-transmission systems may be used for flushing purposes. In the interest of economy, however, either used or reclaimed liquids should be used for flushing, provided they are clean and free of water and insoluble contaminants and do not contain acids resulting from oxidation of the liquids.

FILTER BOWL SAMPLE



1. Discoloration as dark as or darker than reference disk.
2. More than 2 metal chips larger than 0.01 inch in diameter. (About size of sharp pencil dot.)
3. More than 35 very fine but visible metal particles.

DOWNSTREAM SAMPLE



1. Discoloration as dark as or darker than reference disk.
2. More than 1 metal chip larger than 0.01 inch in diameter. (About size of sharp pencil dot.)
3. More than 10 very fine but visible metal particles.

FP.35

Figure 3-3.—Hydraulic liquid contamination test patches.

CAUTION: Diesel fuel oil must not be used for flushing hydraulic systems in active service, because of its poor lubricating qualities and its contaminating effect on the subsequent fill of hydraulic liquid.

While being flushed with an approved hydraulic liquid, power-transmission systems can be operated at full load to raise the temperature of the liquid. Immediately following the warming operation, the system should be drained by opening all drain outlets and disconnecting the hydraulic lines to remove as much of the flushing medium as possible. All filter elements, screens, and chambers should be cleaned with new fluid prior to filling the system with the required service liquid.

CAUTION: The system should not be operated while or after draining the liquid.

Power-transmission systems and their interconnected hydraulic controls whose inner surfaces have been inactivated and treated with a corrosion prevention or preservation compound must be flushed to remove the compound. The latest current instructions for flushing and other operations required to reactivate a particular system must be strictly followed to prevent damage.

Some hydraulic systems are flushed by forcing new liquid into the system under pressure, forcing out the contaminated or decomposed liquid.

Hydraulic liquid which has been contaminated by continuous use in hydraulic equipment or has been expended as a flushing medium must not be used again, but should be discarded in accordance with prevailing instructions.

CAUTION: Never permit high-pressure air to be in direct contact with petroleum base liquids in a closed system, because of the danger of ignition. If gas pressure is needed in a closed system, nitrogen or some other inert gas should be used.

PNEUMATIC GASES

Gases serve the same purpose in pneumatic systems as liquids serve in hydraulic systems. Therefore, many of the same qualities that are considered when selecting a liquid for a hydraulic system must be considered when selecting a gas for a pneumatic system.

QUALITIES

The ideal fluid medium for a pneumatic system must be a readily available gas that is nonpoisonous, chemically stable, free from any acids that cause corrosion of system components, and nonflammable. It should be a gas that will not support combustion of other elements.

The viscosity of gases is not a critical quality to consider in the selection of a medium for pneumatic systems. However, it should be noted that, unlike liquids, the viscosity of gases increases as the temperature increases and decreases as the temperature decreases.

Gases that have these desired qualities do not have the required lubricating power. Therefore, lubrication of the components of a pneumatic system must be arranged by other means. For example, air compressors are provided with a lubricating system, and components are lubricated upon installation or, in some cases, lubrication is introduced into the air supply line.

TYPICAL GASES USED

The two most common gases used in pneumatic systems are compressed air and nitrogen.

NOTE: Compressed air is a mixture of all other gases contained in the atmosphere. However, in this manual it is referred to as one of the gases used as a fluid medium in pneumatic systems.

Compressed Air

The unlimited supply of air and the ease of compression make compressed air the most widely used fluid for pneumatic systems. Although moisture and solid particles must be removed from the air, it does not require the extensive distillation or separation process required in the production of other gases.

Compressed air has most of the desired properties and characteristics of a gas for pneumatic systems. It is nonpoisonous and nonflammable but does contain gases, such as oxygen, which support combustion. One of the most undesirable qualities of compressed air as a fluid medium for pneumatic systems is moisture content. The atmosphere contains varying amounts of moisture in vapor form, the amount depending upon geographic locations and weather conditions. Changes in temperature of compressed air will cause condensation of moisture in the pneumatic system. This condensed moisture is very harmful to the system as it increases the formation of rust and corrosion, dilutes lubricants, and may freeze in lines and components during cold weather. Most pneumatic systems employ devices for the removal of moisture. These components are described in chapter 7.

The supply of compressed air at the required volume and pressure is provided by an air compressor. In some systems the compressor is part of the system with distribution lines leading from the compressor (receiver) to the devices to be operated. Other systems receive their supply from cylinders. However, the cylinders must be charged (filled to the required pressure) at a centrally located air compressor and then connected to the system.

Nitrogen

For all practical purposes, nitrogen is considered to be an inert gas. (Inert is defined as chemically inactive; not combining with other chemicals.) It is not completely inert like helium or argon, for there are many nitrogen compounds, such as nitrate used in fertilizers and explosives. However, nitrogen is very slow to combine chemically with other elements under normal conditions. Nitrogen, as a gas, supports no fires, no living things, and causes no rust or decay of most of the things with which it comes in contact. Due to these qualities, its use is preferred over compressed air in many pneumatic systems, especially aircraft and missile systems.

Nitrogen is obtained by the fractional distillation of air. In many cases, nitrogen is obtained as a byproduct of oxygen-producing plants. Such plants are located at many of the Navy's installations ashore. In addition, some ships, particularly aircraft carriers, are equipped with oxygen/nitrogen plants.

A combination of nitrogen and compressed air is used in some pneumatic systems. Compressed nitrogen is supplied from cylinders, while a compressor provides compressed air to replenish any expended nitrogen and maintains the pneumatic system at the required pressure.

POTENTIAL HAZARDS

All compressed gases are hazardous. Compressed air and nitrogen are neither poisonous nor flammable, but should not be handled carelessly. Some pneumatic systems operate at pressures exceeding 3,000 psi. Lines and fittings have exploded injuring personnel and property. Literally thousands of careless men have blown dust or harmful particles into their eyes by the careless handling of compressed air outlets.

Nitrogen gas will not support life, and when released in a confined space will cause asphyxia (the loss of consciousness as a result of too little oxygen and too much carbon dioxide in the blood). Because compressed air and nitrogen seem so safe in comparison with other gases, do not let overconfidence lead to personal injury.

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When handling gas cylinders, always abide by the color code on the cylinders. For example, a cylinder must not be charged with a gas other than that so indicated by the color code. The color codes for compressed air and nitrogen cylinders are as follows. Cylinders for compressed air are painted black. Cylinders containing oil pumped air have two green stripes painted around the top of the cylinder, while cylinders containing water pumped air have one green stripe. Nitrogen cylinders are painted gray. One black stripe identifies those cylinders for oil pumped nitrogen, and two black stripes identify those cylinders for water pumped nitrogen. In addition to these color codes, the exact identification of the contents is printed in two locations diametrically opposite and parallel to the longitudinal axis to the cylinder. For compressed air and nitrogen cylinders, the lettering is in white.

NOTE: Oil pumped indicates that the air or nitrogen is compressed by an oil lubricated compressor. Air or nitrogen compressed by a water lubricated (or nonlubricated) compressor is referred to as water pumped. Oil pumped nitrogen can be very dangerous in certain situations. For example, nitrogen is commonly used to purge oxygen systems. Oxygen will not burn, but it supports and accelerates combustion and will cause oil to burn easily and with great intensity. Therefore, oil pumped nitrogen must never be used to purge oxygen systems. When the small amount of oil remaining in the nitrogen comes in contact with the oxygen, an explosion may result. In all situations, use only that gas specified by the manufacturer and/or recommended by the Navy.

CONTAMINATION CONTROL

Like hydraulic systems, fluid contamination is also a leading cause of malfunctions in pneumatic systems. In addition to the solid particles of foreign matter which find a way to enter the system, there is also the problem of moisture, as mentioned previously. Most systems are equipped with one or more devices to remove this contamination. These include filters, water separators, and chemical driers, which are discussed in chapter 7. In addition, most systems contain drain valves at critical low points in the system. These valves are opened periodically allowing the escaping gas to purge a large percentage of the contaminants, both solids and moisture, from the system. In some systems these valves are opened and closed automatically, while in others they must be operated manually.

Complete purging is accomplished by removing lines from various components throughout the system and then attempting to pressurize the system. Removal of the lines will cause a high rate of airflow through the system. The airflow will cause the foreign matter to be exhausted from the system.

NOTE: If an excessive amount of foreign matter, particularly oil, is exhausted from any one system, the lines and components should be removed and cleaned or replaced.

Upon the completion of pneumatic system purging and after reconnecting all the system components, the system drain valves should be opened to exhaust any moisture or impurities which may have accumulated. After all drain valves are closed, the system should be serviced with the approved gas, usually nitrogen or compressed air. The system should then be given a thorough operational check and an inspection for leaks and security.

History has indicated that the development of fluid power and its mechanical equipment goes hand in hand with the development of specific fluids for each application. Past breakthrough in high-temperature fluids have shown that, when future equipment requires fluid power, satisfactory systems and fluids will be available. For example, hot gas fluid power systems have been developed and are currently used in missile and space vehicles. The hot gases are obtained by bleeding off the main rocket engine or using a solid or liquid propellent gas generator.

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CHAPTER 4

BASIC SYSTEMS AND CIRCUIT DIAGRAMS

In order to transmit and control power through pressurized fluids, an arrangement of interconnected components is required. Such an arrangement is commonly referred to as a system. The number and arrangement of the components vary from system to system, depending upon the particular application. In many applications, one main system supplies power to several subsystems, which are sometimes referred to as circuits. The complete system may be a small compact unit; more often, however, the components are located at widely separated points for convenient control and operation of the system.

Regardless of the arrangement of the components, it is difficult, if not impossible, to understand the operation and interrelationship of the components by simply observing the operation of the system. This knowledge is required to effectively troubleshoot and maintain a fluid power system. As an aid for personnel who must maintain fluid power equipment, at least one system or circuit diagram is usually provided in the applicable technical publication. By utilizing the applicable diagram, the path of fluid may be traced through the operation of the system. Thus, these diagrams are valuable assets in diagnosing the cause of malfunctions in fluid power systems.

The first part of the chapter describes the functions of the components of a basic fluid power system. Included in this section are descriptions and illustrations denoting the differences between closed-center and open-center fluid power systems. The next part of the chapter covers information concerning the different types of diagrams used to illustrate fluid power circuits, including some of the symbols used to depict fluid power components on diagrams. The last part of the chapter describes and illustrates some of the applications of basic fluid power systems.

COMPONENTS OF A BASIC SYSTEM

The basic components of a fluid power system are essentially the same, regardless of whether the system employs a hydraulic or a pneumatic medium. There are five basic components used in a system. These basic components are as follows:

1. Reservoir or receiver.
2. Pump or compressor.
3. Lines (pipe, tubing, or flexible hose).
4. Directional control valve.
5. Actuating device.

The term RESERVOIR is associated with hydraulic systems and the term RECEIVER with pneumatic systems. The primary purpose of a reservoir or receiver is to provide a storage space for fluid used in the respective systems. The two components, however, differ in some respects. In the case of the receiver, a volume of fluid (gas) is stored under pressure and is supplied to the pneumatic system as needed to operate the system. The pressure of the gas provides the flow and force required to operate the system. After the gas is used for an operation, it is exhausted to the atmosphere and a new supply of fluid is compressed in the receiver. In converse, the fluid in most hydraulic reservoirs is not pressurized. Although some hydraulic reservoirs are pressurized, this pressure does not supply the force to operate the system but is limited to the amount necessary to insure a supply of fluid to the hydraulic pump at all times. In addition, the fluid of a hydraulic system is used over and over again, flowing from the reservoir to the other components, back to the reservoir, to the components, etc. Therefore, a well designed reservoir also serves as a heat exchanger to control the temperature of the fluid and as a place to filter and clean the fluid. Reservoirs and receivers are discussed in detail in chapter 7.

A fluid power system requires a power unit to convert mechanical energy into fluid energy. In pneumatic systems, this unit is referred to as a COMPRESSOR, while in hydraulic systems, this unit is called a PUMP. Like the reservoirs and receivers discussed in the preceding paragraph, the pump and compressor differ in some respects. These differences and detailed information concerning the types and operation of pumps and compressors are covered in chapter 8 of this training manual. Basically, the compressor, which is driven by some outside power source, compresses the fluid (gas) in the receiver. The hydraulic pump, also driven by an outside power source, provides a flow of fluid to a hydraulic system.

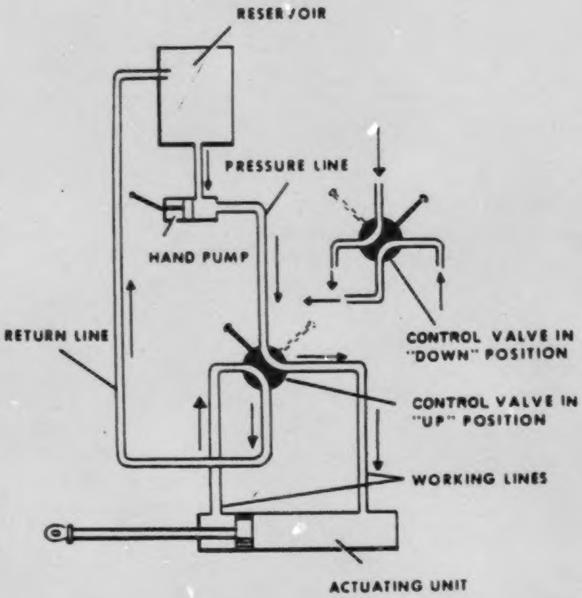
The LINES are the medium for transmitting the fluid from one component to another. This is normally accomplished by using pipe, tubing, or flexible hose for interconnecting reservoirs to pumps, pumps to valves, valves to cylinders, etc. The different types of fluid lines and connectors are covered in chapter 5.

The DIRECTIONAL CONTROL VALVE (also referred to as a selector valve) is a device which directs a flow of fluid to and from the actuating device. Some of the most common types of directional control valves and their applications are described and illustrated in chapter 11.

The ACTUATING DEVICE of a fluid power system is that component which converts the fluid pressure into useful work. Actuators perform the opposite function of hydraulic pumps and pneumatic compressors in that they convert fluid energy into mechanical energy. Common types of actuating devices are the cylinder, which provides linear motion, and motors, which provide rotary motion. The types and operation of actuating devices are covered in chapter 12.

These five basic components, when combined into one unit, are the basis for a fluid power system. An example of a basic hydraulic system is illustrated in figure 4-1.

The flow of fluid can be traced readily from the reservoir through the pump to the directional control valve. With the control valve in the UP position, as shown, the flow of fluid provided by the pump flows through the valve to the right-hand end of the actuating cylinder. Fluid pressure then forces the piston to the left and, at the same time, the fluid on the left side of the piston is forced out of the cylinder, through the control valve, and back to reservoir through the return line.



FP.36

Figure 4-1.—Basic hydraulic system, hand pump operated.

When the control valve is moved to the DOWN position, as shown in the insert of figure 4-1, the fluid flows from the pump through the control valve to the left side of the actuating cylinder, thus reversing the process. Movement of the piston can be stopped at any time simply by moving the control valve to neutral. In this position, all four ports are closed and pressurized fluid is trapped in both working lines.

The example shown in figure 4-1 could very well represent a basic pneumatic system by replacing the reservoir with a receiver and the pump with a compressor and reversing their positions in the system. Thus the fluid would flow from the compressor into the receiver and from the receiver to the control valve. The return fluid from the actuating cylinder is exhausted from the control valve; therefore, the return line, as shown in figure 4-1, is not required in a pneumatic system.

This basic system is one from which any system can be derived. The hand pump may be replaced with a power pump and the actuating device may be a motor. Additions may be added for the purposes of providing additional sources of power, operating additional cylinders, making operation more automatic, or increasing reliability; but these additions are all made on the framework of the basic system.

With the addition of a few components, a basic system can be improved into a more workable system. Figure 4-2 shows a basic system with the addition of a power-driven pump and the following essential components: Filter, pressure regulator, accumulator, pressure gage, relief valve, and two check valves. The functions of each of these components are briefly explained in the following paragraphs. Detailed information concerning the types, construction, and operating features of these components are described later in this manual.

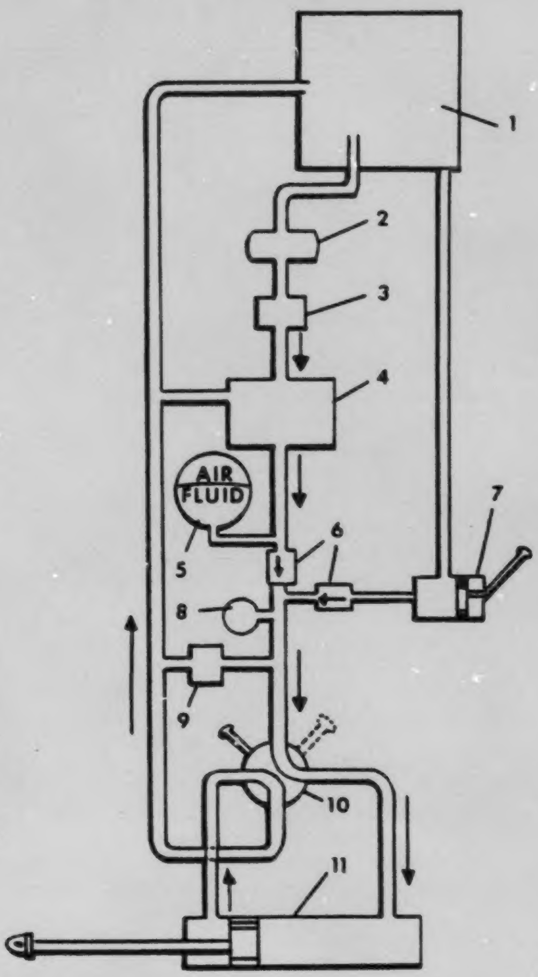
The **FILTER** removes foreign particles from the fluid, preventing dust, grit, and other undesirable matter from entering the system.

The purpose of the **PRESSURE REGULATOR** is to unload or relieve the power-driven pump when the desired pressure in the system is reached. It is therefore often referred to as an unloading valve. When the pressure in the system builds up to the desired point, a valve in the pressure regulator opens and fluid from the pump is bypassed back to the reservoir. The bypass line is shown if figure 4-2 leading from the regulator to the reservoir. At the same time, the pressure in the remainder of the system is maintained at the desired pressure. When this pressure drops, due to the operation of an actuating unit or internal or external leakage, the valve in the regulator closes, allowing the pressure in the system to build up to the desired amount.

Many fluid power systems do not use a pressure regulator, but have other means of unloading the pump and maintaining system pressure. Such methods are described later in this manual.

The **ACCUMULATOR** serves several purposes in a hydraulic system. It serves as a cushion or shock absorber by absorbing pressure surges in the system, and it stores enough fluid under pressure to provide for emergency operation of certain actuating units. It is designed with a compressed-air (or nitrogen) chamber separated from the hydraulic fluid by a flexible diaphragm, synthetic rubber bladder, or movable piston.

The **PRESSURE GAGE** indicates the amount of pressure in the system.



1. Reservoir.
2. Power pump.
3. Filter.
4. Pressure regulator.
5. Accumulator.
6. Check valves.
7. Hand pump.
8. Pressure gage.
9. Relief valve.
10. Control valve
11. Actuating device.

FP.37

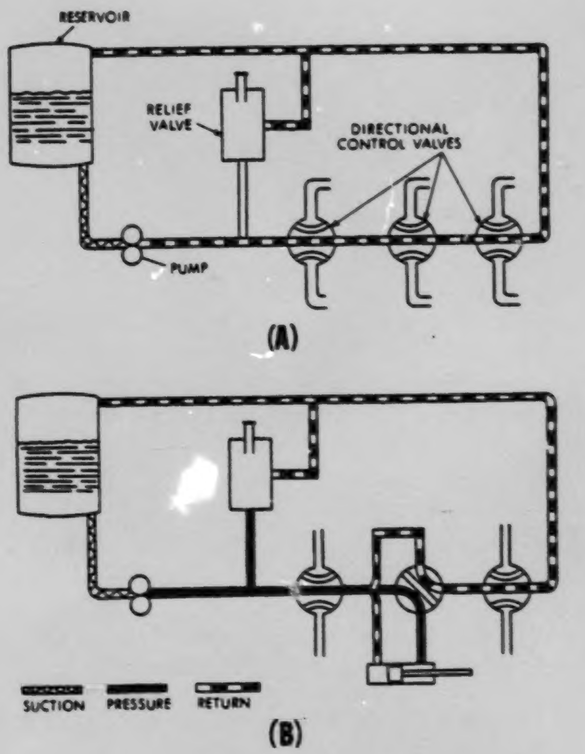
Figure 4-2.—Basic system with addition of power pump and other components.

The RELIEF VALVE is a safety valve installed in the system so that fluid is bypassed through the valve back to the reservoir in case excessive pressure is built up in the system.

CHECK VALVES allow the flow of fluid in one direction only. There are numerous check valves installed at various points in most fluid power systems. A careful study of figure 4-2 will reveal why the two check valves are necessary in the system. (The arrow on each check valve points toward the direction of free flow.) One check valve prevents power-pump pressure from entering the hand pump line; the other prevents hand-pump pressure from being directed to the accumulator. In a system of this type, the power pump is used in the normal operation of the system. The hand pump serves as an emergency means of operating the system in case of power pump failure. The hand pump may also be used as a means for checking and troubleshooting many of the components of the system.

In the system described in the preceding paragraphs, the fluid in the system from the pump (or regulator) to the directional control valve is under pressure when the pump is operating. Any number of subsystems may be incorporated in such a system with a separate directional control valve for each subsystem. The directional control valves are arranged in parallel whereby system pressure acts equally on all control valves. This type system is referred to as a closed-center system.

Another type of system which is sometimes used in hydraulically operated equipment is the open-center system. An open-center system is one having fluid flow, but no pressure in the system when the actuating mechanisms are idle. The pump circulates the fluid from the reservoir, through the directional control valves, and back to the reservoir. (See fig. 4-3 (A).) Like the closed-center system, the open-center system may employ any number of subsystems with a directional control valve for each subsystem. Unlike the closed-center system, the directional control valves of an open-center system are always connected in series with each other, an arrangement whereby the system pressure line goes through each directional control valve. Fluid is always allowed free passage through each control valve and back to the reservoir until one of the control valves is positioned to operate a mechanism.



FP.38

Figure 4-3.—Basic open-center hydraulic system.

When one of the directional control valves is positioned to operate an actuating device, as shown in view (B) of figure 4-3, fluid is directed from the pump through one of the working lines to the actuator. With the control valve in this position, the flow of fluid through the valve to the reservoir is blocked. Thus, the pressure of the fluid builds up in the system to overcome the resistance and moves the piston of the actuating cylinder. The fluid from the other end of the actuator returns to the control valve through the opposite working line and flows back to the reservoir.

Several different types of directional control valves are used in conjunction with the open-center system. One type is the manually engaged and manually disengaged. After this type valve is manually moved to an operating

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position and the actuating mechanism reaches the end of its operating cycle, pump output continues until the system relief valve setting is reached. The relief valve then unseats and allows the fluid to flow back to the reservoir. The system pressure remains at the pressure setting of the relief valve until the directional control valve is manually returned to the neutral position. This action reopens the open-center flow and allows the system pressure to drop to line resistance pressure.

Another type of open-center directional control valve is the manually engaged and pressure disengaged. This type valve is similar to the valve discussed in the preceding paragraph; however, when the actuating mechanism reaches the end of its cycle and the pressure continues to rise to a predetermined pressure, the valve automatically returns to the neutral position and, consequently, to open-center flow.

One of the advantages of the open-center system is that the continuous pressurization of the system is eliminated. Since the pressure is gradually built up after the directional control valve is moved to an operating position, there is very little shock from pressure surges. This provides a smooth operation of the actuating mechanisms; however, the operation is slower than the closed-center system in which the pressure is available the moment the directional control valve is positioned. Since most applications require instantaneous operation, closed-center systems are the most widely used.

CIRCUIT DIAGRAMS

As mentioned previously, the ability to read diagrams is a basic requirement for understanding the operation of fluid power systems. To understand the diagrams of a system, first requires a knowledge of the symbols used in the schematic diagrams.

SYMBOLS

The Navy uses two Military Standards which list mechanical symbols that shall be used in the preparation of drawings where symbolic representation is desired. These two Military Standards are as follows:

1. Military Standard, Mechanical Symbols (Other than Aeronautical, Aerospacecraft, and Spacecraft Use), Part 1, MIL-STD-17B-1.
2. Military Standard, Mechanical Symbols for Aeronautical, Aerospacecraft, and Spacecraft Use, Part 2, MIL-STD-17B-2.

Some of the more pertinent symbols used in fluid power systems have been selected from these two standards and are depicted in tables 4-1 and 4-2. Symbols from MIL-STD-17B-2 are presented in table 4-1 and symbols from MIL-STD-17B-1 in table 4-2.

NOTE: The equipment symbols illustrated in table 4-1 show only the basic outline of each component. It is stated in MIL-STD-17B-2 that schematic diagrams should show a cutaway section of each component at least in schematic form.

While the symbols illustrated in this chapter are not all encompassing, they do provide a basis for the man working with fluid power systems to build upon. For more detailed information concerning the symbols used in fluid power diagrams, the above mentioned Military Standards should be consulted. Additional information concerning symbols and the reading of diagrams is contained in Blueprint Reading and Sketching, NavPers 10077 (Series).

USE OF DIAGRAMS

As emphasized earlier in this chapter, in order to troubleshoot fluid power systems intelligently, the mechanic or technician must be familiar with the system at hand. He must know the function of each component in the system and have a mental picture of its location in relation to other components in the system. These can best be achieved by studying the diagrams of the system.

There are many types of diagrams; however, those which are the most pertinent to fluid power systems may be divided into two classes. These diagrams are usually referred to as pictorial and schematic diagrams and are usually provided by the manufacturer to aid the maintenance man in understanding and troubleshooting the system and equipment. There may be instances where a schematic diagram will be shown as a pictorial diagram, or the diagram may consist of a combination of the two.

A diagram, whether it is a pictorial or schematic diagram, may be defined as a graphic representation of an assembly or system, indicating the various parts and expressing the methods or principles of operation. As a general

Table 4-1.—Aeronautical mechanical symbols.

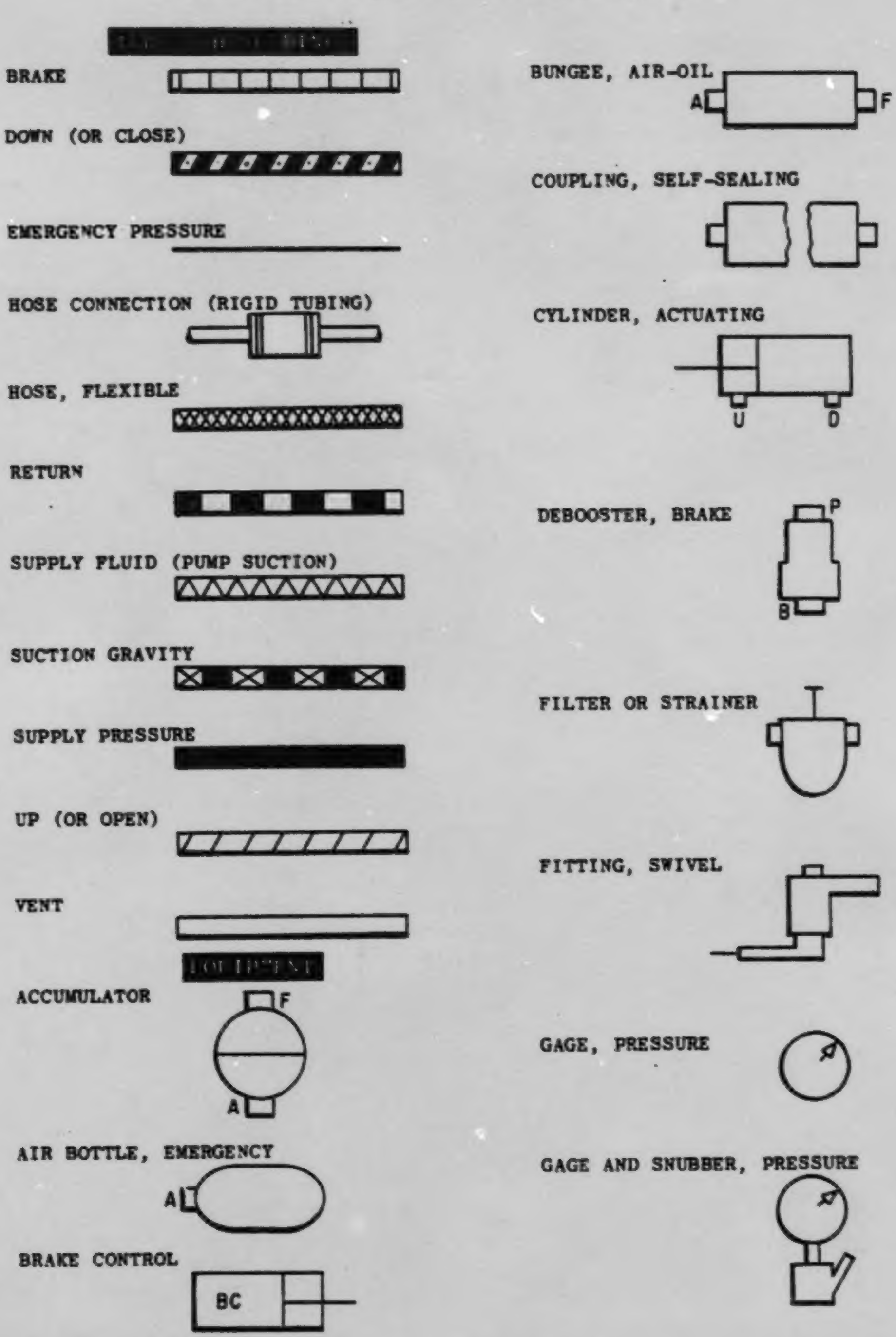
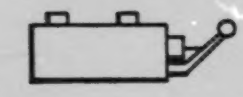
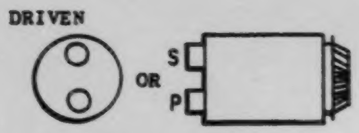

BRAKE
DOWN (OR CLOSE)
EMERGENCY PRESSURE
HOSE CONNECTION (RIGID TUBING)
HOSE, FLEXIBLE
RETURN
SUPPLY FLUID (PUMP SUCTION)
SUCTION GRAVITY
SUPPLY PRESSURE
UP (OR OPEN)
VENT
ACCUMULATOR
F
A
AIR BOTTLE, EMERGENCY
A
BRAKE CONTROL
BC
BUNGEE, AIR-OIL
A
F
COUPLING, SELF-SEALING
CYLINDER, ACTUATING
U
D
DEBOOSTER, BRAKE
P
B
FILTER OR STRAINER
FITTING, SWIVEL
GAGE, PRESSURE
GAGE AND SNUBBER, PRESSURE

Table 4-1.—Aeronautical mechanical symbols—Continued.

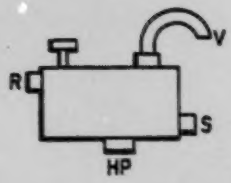
PUMP, HAND



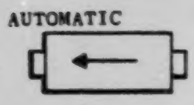
PUMP, POWER DRIVEN



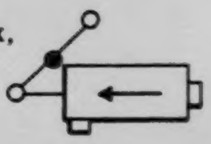
RESERVOIR



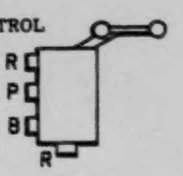
VALVE, CHECK, AUTOMATIC



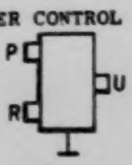
VALVE, CHECK, MANUAL



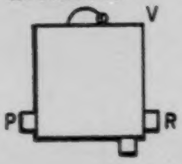
VALVE, BRAKE CONTROL



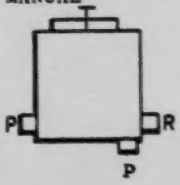
VALVE, GUN CHARGER CONTROL



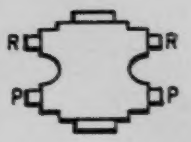
VALVE, PRESSURE REGULATING (UNLOADING) AUTOMATIC



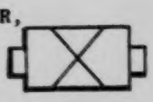
VALVE, PRESSURE REGULATING (UNLOADING) MANUAL



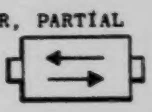
VALVE, RELIEF



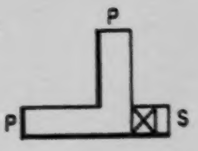
VALVE, RESTRICTOR, BOTH WAYS



VALVE, RESTRICTOR, PARTIAL ONE-WAY



VALVE, SHUTTLE



VALVE OR SELECTOR, DIRECTIONAL CONTROL

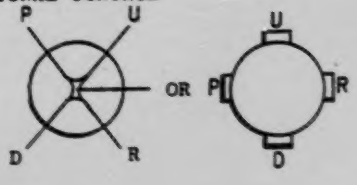


Table 4-1.--Aeronautical mechanical symbols--Continued.

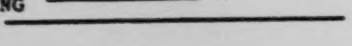
[illegible]

A - AIR	HP - HANDPUMP
B - BRAKE	P - PRESSURE
BC - BRAKE CONTROL	R - RETURN
D - DOWN (OR CLOSE)	S - SUCTION (OR SUPPLY)
F - FLUID (LIQUID)	U - UP (OR OPEN)

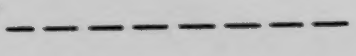
Table 4-2.--Mechanical symbols other than aeronautical.

FLOW LINES

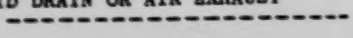
LINES, WORKING



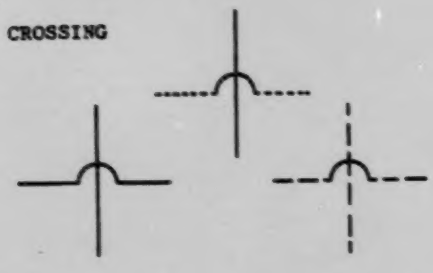
LINES, PILOT



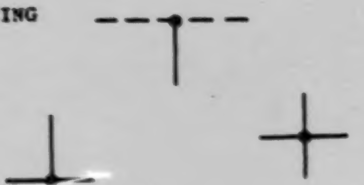
LINES, LIQUID DRAIN OR AIR EXHAUST



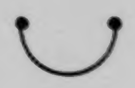
LINES, CROSSING



LINES, JOINING



LINES, FLEXIBLE



FLOW, DIRECTION OF

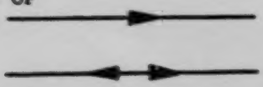
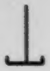
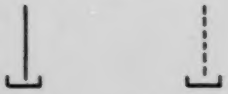


Table 4-2.--Mechanical symbols other than aeronautical--Continued.

LINES TO RESERVOIR
BELOW FLUID LEVEL

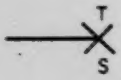


ABOVE FLUID
LEVEL

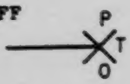


PLUG OR PLUGGED CONNECTION

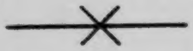
TESTING STATION



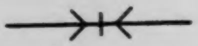
FLUID POWER TAKE-OFF
STATION



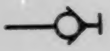
RESTRICTION, FIXED



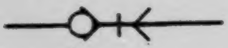
QUICK DISCONNECT
WITHOUT CHECKS



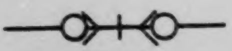
WITH CHECKS
DISCONNECTED



WITH ONE CHECK



WITH TWO CHECKS



PUMPS, COMPRESSORS
& ROTARY MOTORS

BASIC SYMBOL
ENVELOPE

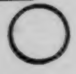
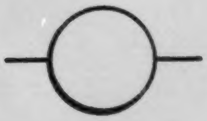


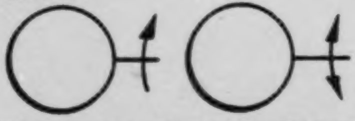
Table 4-2.—Mechanical symbols other than aeronautical—Continued.

PORTS



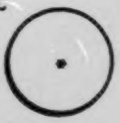
LINES OUTSIDE ENVELOPE ARE NOT PART OF SYMBOL, BUT REPRESENT FLOW LINES CONNECTED THERETO.

SHAFTS, ROTATING



ARROW INDICATES DIRECTION OF ROTATION BY ASSUMING IT IS ON NEAR SIDE OF SHAFT.

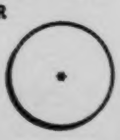
PUMPS, HYDRAULIC



APPROPRIATE SYMBOLS SHALL BE ADDED TO INDICATE SHAFTS, CONNECTING LINES, AND METHOD OF CONTROL.
*TYPE OF PUMP SHALL BE INDICATED WITHIN BASIC SYMBOL BY APPROPRIATE LETTERS LISTED BELOW.

PF	FIXED DISPLACEMENT
PK	KINETIC - CENTRIFUGAL
PV	VARIABLE DISPLACEMENT

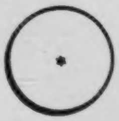
COMPRESSORS, AIR



APPROPRIATE SYMBOLS SHALL BE ADDED TO INDICATE SHAFTS, CONNECTING LINES, AND METHOD OF CONTROL.
*TYPE OF COMPRESSOR SHALL BE INDICATED WITHIN BASIC SYMBOL BY APPROPRIATE LETTERS LISTED BELOW.

CF	FIXED DISPLACEMENT
CK	KINETIC

FLUID MOTORS, ROTARY

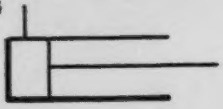


APPROPRIATE SYMBOLS SHALL BE ADDED TO INDICATE SHAFTS, CONNECTING LINES, AND METHOD OF CONTROL.
*TYPE OF MOTOR SHALL BE INDICATED WITHIN BASIC SYMBOL BY APPROPRIATE LETTERS LISTED BELOW.

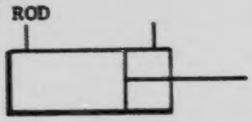
MF	FIXED DISPLACEMENT
MO	OSCILLATING
MV	VARIABLE DISPLACEMENT

CYLINDERS

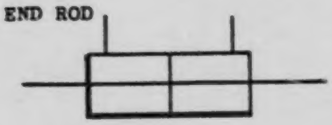
SINGLE ACTING



DOUBLE ACTING
SINGLE END ROD

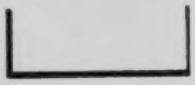


DOUBLE END ROD

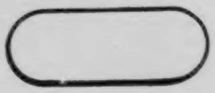


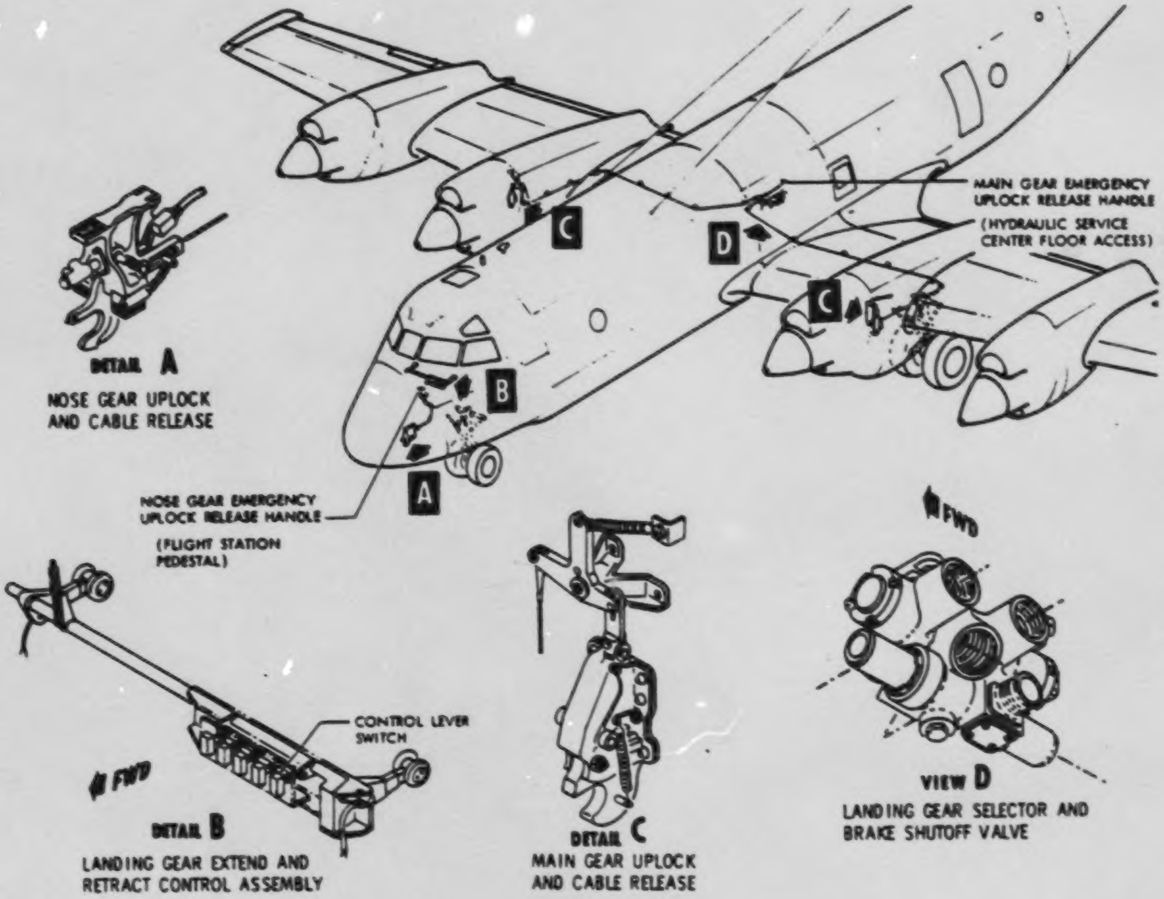
RESERVOIRS

FOR LIQUID, VENTED



PRESSURIZED,
RECEIVER FOR AIR OR OTHER GASES




MAIN GEAR EMERGENCY UPLOCK RELEASE HANDLE
(HYDRAULIC SERVICE CENTER FLOOR ACCESS)
C
D
C
B
A
DETAIL A
NOSE GEAR UPLOCK AND CABLE RELEASE
NOSE GEAR EMERGENCY UPLOCK RELEASE HANDLE
(FLIGHT STATION PEDESTAL)
FWD
CONTROL LEVER SWITCH
FWD
DETAIL B
LANDING GEAR EXTEND AND RETRACT CONTROL ASSEMBLY
DETAIL C
MAIN GEAR UPLOCK AND CABLE RELEASE
VIEW D
LANDING GEAR SELECTOR AND BRAKE SHUTOFF VALVE

FP.39

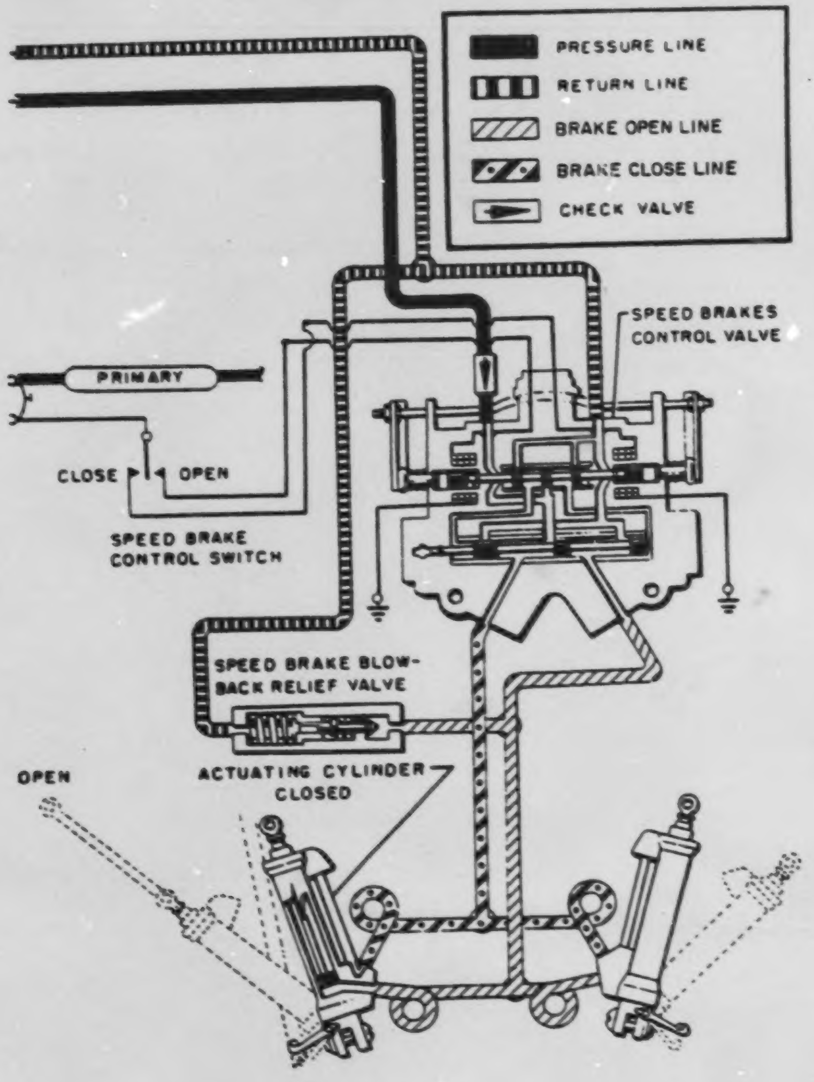
Figure 4-4.—Example of a pictorial diagram.

rule, the various components are indicated by symbols (tables 4-1 and 4-2) in schematic diagrams, while drawings of the actual components are used in pictorial diagrams.

Pictorial Diagrams

Pictorial diagrams show general location, function, and appearance of parts and assemblies. This type diagram is sometimes referred to as an installation diagram. An example of a pictorial diagram is shown in figure 4-4. This is a diagram of the landing gear control system of a Navy aircraft. It shows the location of each of the components within the aircraft on the principal view. Each letter (A, B, C, etc.) on the principal view refers to a detail view located elsewhere on the diagram. Each detail view is an enlarged drawing of a portion of the system identifying each of the principal components.

Diagrams of this type are invaluable to maintenance personnel in identifying and locating components, and understanding the principle of operation of the system.


PRESSURE LINE
RETURN LINE
BRAKE OPEN LINE
BRAKE CLOSE LINE
CHECK VALVE
SPEED BRAKES CONTROL VALVE
PRIMARY
CLOSE
OPEN
SPEED BRAKE CONTROL SWITCH
SPEED BRAKE BLOW-BACK RELIEF VALVE
OPEN
ACTUATING CYLINDER CLOSED

FP.40

Figure 4-5.—Example of schematic diagram.

Schematic Diagrams

The primary purpose of a schematic diagram is to enable the maintenance man to trace the flow of fluid, component by component. This type of diagram does not necessarily indicate the physical location of the various components, but does show the relation of each component to the other components within the system.

Figure 4-5 is an example of a schematic diagram of a speed brake system used in one model of Navy aircraft. Notice that this diagram does not indicate the physical location of the individual components within the aircraft, but does locate components with respect to each other in the system. For example, the check valve in figure 4-5 is not necessarily located immediately above the speed brake control valve. The diagram does indicate, however, that the check valve is located in the pressure line and that the pressure line leads into the control valve.

Schematic diagrams of this type are used mainly in troubleshooting. Note that each line (pressure, return, brakes open, and brakes closed) is coded for easy reading and tracing the flow. An explanation of the codes is given in the legend at the top righthand corner of the illustration. On many diagrams of this type, different colors are used to represent the various lines. Each component is identified by name, and its location within the system can be ascertained by noting which lines lead into and out of the component.

The system illustrated in figure 4-5 is actually one of several subsystems operated by one power system. Although it is a rather complex system, it is shown at this point in the manual to emphasize the importance of using diagrams in maintaining fluid power systems. A brief description of the system including the general function of the major components follow.

In tracing the flow of fluid through the system, it can be seen that the first component in the pressure line is a check valve. The arrow on the valve indicates the direction of flow through the valve. This valve is located in the pressure line for the purpose of preventing speed brake pressure from dropping when the main system pressure drops momentarily, as when another actuating system is operated.

The next unit in the line is the speed brake control valve. This valve is a four-port valve which is connected to pressure, return, and to each actuating line.

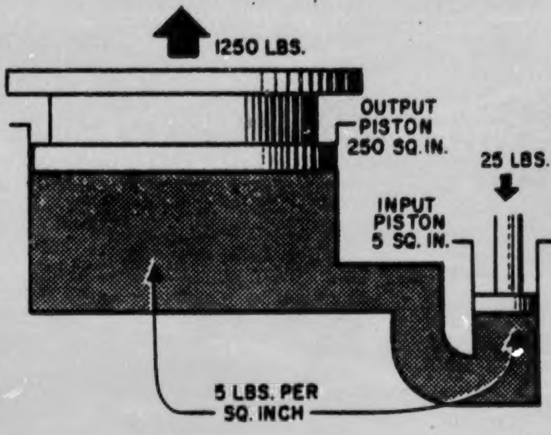
When the control valve is placed in brakes open position, fluid under pressure flows through the brakes open line to the actuating cylinders, opening the speed brakes. Also in the brakes open line is a blow-back relief valve. This valve is also connected to the return line. The purpose of this valve is to protect the speed brakes against excessive wind blasts. For example, if the pilot opened the speed brakes at an airspeed greater than that for which the speed brakes are designed, the blow-back relief valve would open, allowing the excess fluid pressure to return to the reservoir. Thus, the speed brakes would be blown back to the closed position.

SIMPLE HYDRAULIC AND PNEUMATIC SYSTEMS

There are several applications of fluid power which require only a simple system; that is, a system which employs only a few components in addition to the five basic components. A few of these applications are presented in the following paragraphs. The operation of these systems is briefly explained at this time so that the reader knows the purpose of the different components and can better understand the functions and operation of these components as they are presented in the following chapters. Examples of the more complex fluid power systems are described in chapter 13.

HYDRAULIC JACK

The hydraulic jack is perhaps one of the simplest forms of a fluid power system. By moving the handle of a small device, an individual can lift a load weighing several tons. A small initial force exerted on the handle is transmitted by means of a fluid to a much larger area. This becomes readily understood by studying figure 4-6. The small input piston has an area of 5 square inches and is directly connected to a large cylinder with an output piston having an area of 250 square inches. The top of this piston forms a lift platform.



FP.41

Figure 4-6.—Hydraulic jack.

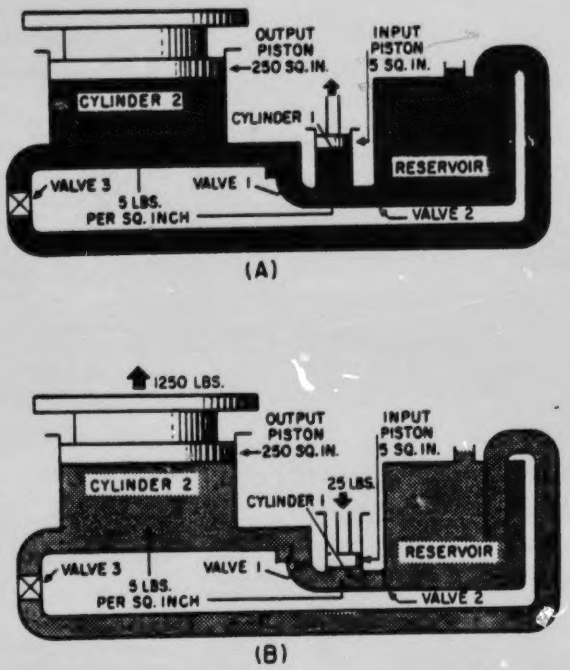
If a force of 25 pounds is applied to the input piston, it produces a pressure of 5 pounds per square inch in the fluid, that is, of course, if a sufficient amount of resistant force is acting against the top of the output piston. Disregarding friction loss, this pressure acting on the 250 square inch area of the output piston will support a resistance force of 1,250 pounds. In other words, this pressure could overcome a force of slightly under 1,250 pounds. An input force of 25 pounds has been transformed into a working force of more than half a ton. However, for this to be true requires that the distance traveled by the input piston be 50 times as great as that traveled by the output piston. Thus, for every inch that the input piston moves, the output piston will move only one-fiftieth of an inch.

This would be ideal if the output piston needed to move only a short distance. However, in most instances, the output piston would have to be capable of moving a greater distance to serve a practical application. The device shown in figure 4-6 is not capable of moving the output piston farther than that shown. Therefore, some other means must be employed to raise the output piston to a greater height.

The output piston can be raised higher and maintained at this height if valves are installed as shown in figure 4-7. In this illustration the jack is designed so that it may be raised, lowered, or held at a constant height. These results are attained by introducing a number of valves, and also a reserve supply of fluid to be used in the system.

Notice that this system contains the five basic components—the reservoir, cylinder (1) which serves as a pump, valve (3) which serves as a directional control valve, cylinder (2) which serves as the actuating device, and lines to transmit the fluid to and from the different components. In addition, this system contains two valves (1) and (2) whose functions are explained in the following discussion.

As the input piston is raised (fig. 4-7 (A)), valve (1) is closed by the back pressure from the weight of the output piston. At the same time, valve (2) is opened by the head of the fluid in the reservoir. This forces fluid into cylinder (1). When the input piston is lowered (fig. 4-7 (B)), a pressure is developed in cylinder (1). When this pressure exceeds the head in the reservoir, it closes valve (2) and when it exceeds the back pressure from the output piston, it opens valve (1), forcing fluid into the pipeline. The pressure from cylinder (1) is thus transmitted into cylinder (2), where it acts to raise the output piston with its attached lift platform. When the input piston is again raised, the pressure in cylinder (1) drops below that in cylinder (2) causing valve (1) to close. This prevents the return of fluid and holds the output piston with its attached lift platform at its new level. During this stroke, valve (2) opens again allowing a new supply of fluid into cylinder (1) for the next power (downward) stroke of input piston. Thus, by repeated strokes of the input piston, the lift platform can be progressively raised. To lower the lift platform, valve (3) is opened, and the fluid from cylinder (2) is returned to the reservoir.



FP.42

Figure 4-7.—Hydraulic jack; (A) Up stroke; (B) downstroke.

HYDRAULIC LIFT

The hydraulic lift functions very similar to the hydraulic jack. The basic difference between the two is the media used to transmit the force.

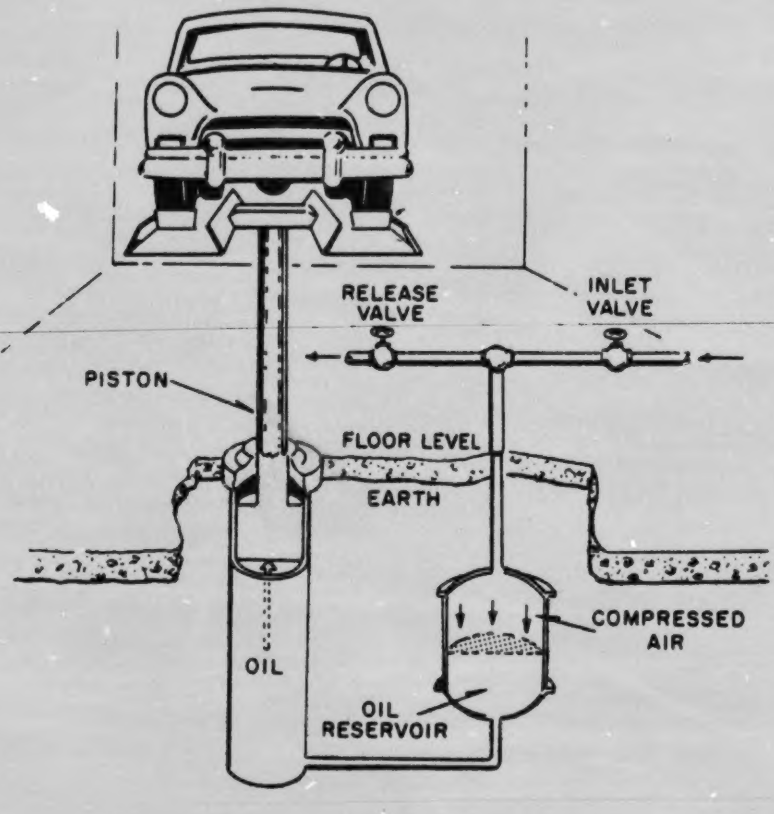
In the hydraulic lift, air pressure applied to the surface of oil in a reservoir is transmitted by the oil to the output piston on the hydraulic lift. (See fig. 4-8.) Using the compressed air as the input piston, the oil as a means of transmitting the force, and the lift attached to the output piston, a means is provided for lifting a heavy vehicle. When the release valve is opened, the compressed air pressure decreases, the oil returns to the reservoir, and the lift is lowered.

HYDRAULIC BRAKES

The hydraulic brake system used in the automobile is a multiple piston system. A multiple piston system allows forces to be transmitted to two or more pistons in the manner indicated in figure 4-9. Note that the pressure set up by the force applied to the input piston (1) is transmitted undiminished to both output pistons (2) and (3), and that the resultant force on each piston is proportional to its area. The multiplication of forces from the input piston to each output piston is the same as that explained earlier.

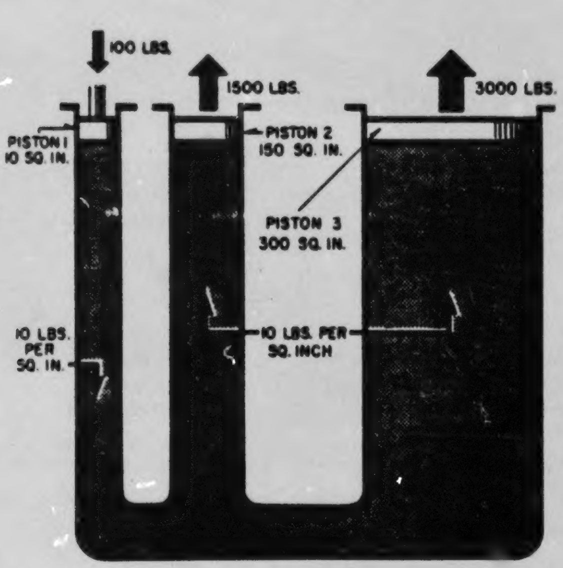
The four-wheel brake system commonly used on automobiles is a practical application of the multiple piston system. (See fig. 4-10.)

NOTE: Many of the modern automobiles are equipped with power (vacuum) assist for the operation of the master cylinder. In the last few years, dual master cylinders are incorporated



FP.43

Figure 4-8.—Hydraulic lift.



FP.44

Figure 4-9.—Multiple piston system.

as a standard safety feature. In addition, some automobiles are equipped with disc brakes. However, the hydraulic system from the master cylinder (s) to the wheel cylinders on most automobiles operates similar to the system illustrated in figure 4-10 and described in the following paragraphs.

When the brake pedal is depressed, the pressure on the brake pedal moves the piston within the master cylinder, forcing the brake fluid from the master cylinder through the tubing and flexible hose to the wheel cylinders. The wheel cylinders contain two opposed output pistons, each of which is attached to a brakeshoe fitted inside the brake drum. Each output piston pushes the attached brakeshoe against the wall of the brakedrum, thus retarding the rotation of the wheel. When pressure on the pedal is released, the springs on the brakeshoes return the wheel cylinder pistons to their released positions. This action forces the displaced brake fluid back through the flexible hose and tubing to the master cylinder.

The force applied to the brake pedal produces a proportional force on each of the output pistons, which in turn apply the brakeshoes frictionally to the turning wheels to retard rotation. If all eight output pistons were the same size, the force exerted on each brakeshoe would be exactly the same, provided frictional losses from the master cylinder to each wheel were equal. Likewise, if the brake-

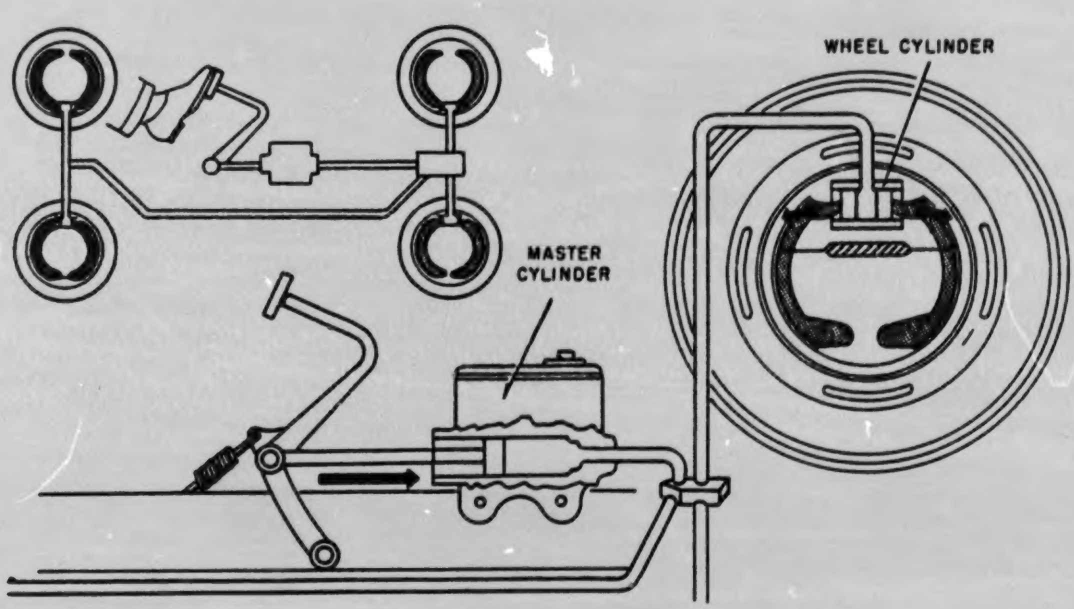


Figure 4-10.—An automobile brake system.

FP.45

shoes were identical, each wheel would be equally retarded.

In actual brake designs, it is customary to use a greater piston area for the front wheels than for the rear. This is to compensate for the transfer of weight to the front of the automobile when the brakes are applied. Due to inertia, the automobile tends to continue to move when the brakes are applied. This increases the concentration of weight at the front end and decreases the concentration of weight at the rear. As a result, the front brakes are required to do more work than the rear and, therefore, require a greater piston area.

DOORSTOP

A doorstop is a mechanism for reducing the speed of a closing door. Doorstops vary in size, shape, design, media, and the principle used to control the door's movement. Hydraulic doorstops are normally used in controlling heavy doors, while pneumatic doorstops are used for lighter type doors. The most commonly used doorstop consists of a cylinder and piston especially designed to cushion or buffer the quick movements of the closing door.

In the pneumatic doorstop, the cushion or buffer effect is attained by the transmission of the motion to the piston rod, which thereupon forces the piston head against the volume of air within the cylinder. The air is compressed and absorbs most of the motion, while graduated holes in the cylinder permit the air to escape slowly and the piston and door are brought gradually to rest.

In the hydraulic type, a liquid is used to cushion the motion of the door. Two cylinders are generally connected by an orifice through which the liquid is forced as the door is opened or closed. The door can thus close only as rapidly as the liquid can be moved through the orifice.

AIRBRAKES

Airbrakes were developed to enable the driver to apply sufficient braking action to the wheels of high-speed, heavily loaded vehicles. With modern airbrake systems, the brake pedal is merely a controlling device for the braking force, which is compressed air. On a vehicle that tows trailers provided with airbrakes, an additional hand controller is provided, which may be operated separately or in conjunction with the pedals. Airbrakes are a form of power brakes. Being more powerful than the hydraulic brakes previously described, they must be larger so that the individual brake will have a greater braking area.

In an airbrake system (fig. 4-11), an engine-driven air pump or compressor is used to compress air and force it into a reservoir, where it is stored under pressure and made available for operating the brakes. The compressed air is released from the reservoir to the brake lines by an air valve operated by the brake pedal. This released air goes to the brake chambers located close to the wheel brakes. Each brake chamber contains a flexible diaphragm and plate. The force of the compressed air admitted to the chamber causes the diaphragm to move the plate, and operates the brake shoes through mechanical linkage. Considerable force is available for braking since the operating pressure may be as high as 100 pounds per square inch. All brakes on a vehicle, and on a trailer when one is used, are operated by special regulating devices.

AIR-OVER-HYDRAULIC BRAKE SYSTEM

The air-over-hydraulic brake system uses the principle of the hydraulic brake to operate the wheel brake cylinders and provide braking action. However, the hydraulic pressure for the wheel brake cylinders is not supplied from the master cylinder. Instead, there are two circuits. The first leads from the air-hydraulic cylinder and admits air pressure which actuates this cylinder by moving an air piston that is connected to the hydraulic piston. The hydraulic piston then applies the hydraulic pressure that produces the braking action. The air is admitted by the action of valves controlled by the hydraulic pressure from the master cylinder.

An air-over-hydraulic brake system is shown in figure 4-12. Air pressure is supplied by a compressor and stored in reservoirs. The master cylinder is similar to the master cylinder used in hydraulic brake systems. Also, the wheel brake cylinders and wheel brake construction are very similar to that used in conjunction with hydraulic brake systems. The essential difference between the straight hydraulic brake system and the air-over-hydraulic brake system lies in the air-hydraulic cylinder. This cylinder consists of three essentials: a large diameter air piston; a small diameter

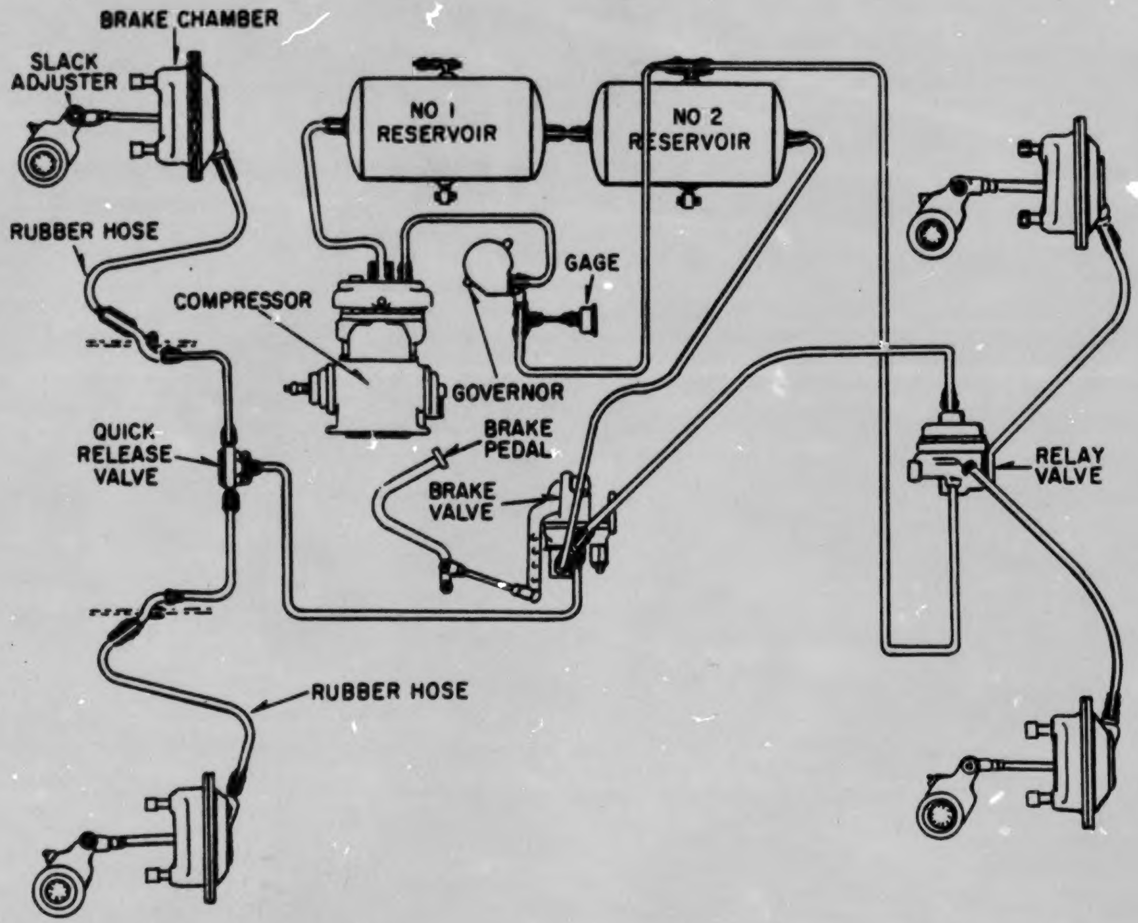
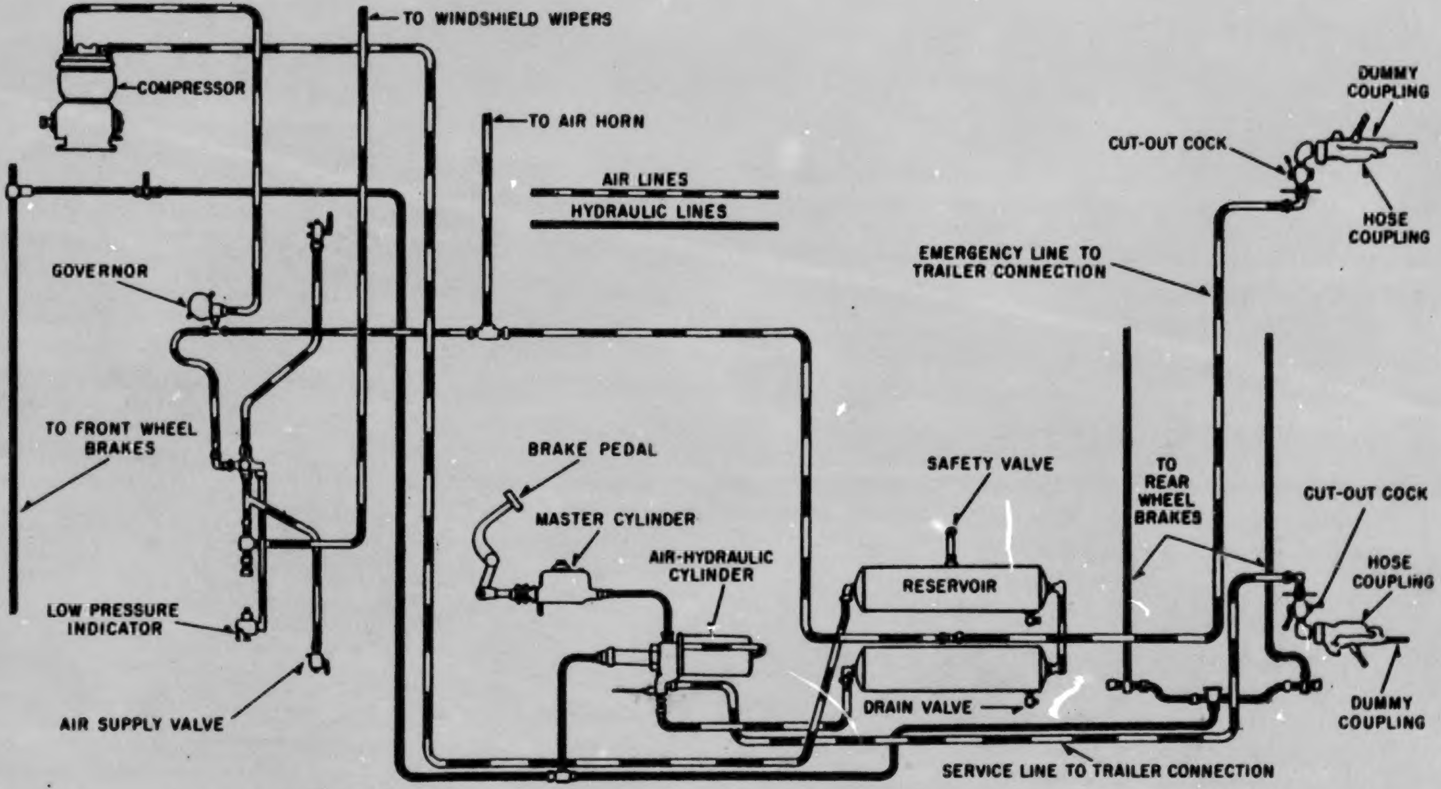

BRAKE CHAMBER
SLACK ADJUSTER
NO 1 RESERVOIR
NO 2 RESERVOIR
RUBBER HOSE
GAGE
COMPRESSOR
GOVERNOR
BRAKE PEDAL
QUICK RELEASE VALVE
BRAKE VALVE
RELAY VALVE
RUBBER HOSE

Figure 4-11.—Typical airbrake system. FP.46

hydraulic piston in tandem with the air piston (both on the same rod); and a set of valves controlled by hydraulic pressure from the master cylinder for admitting air into the air cylinder section of the air-hydraulic cylinder.

The air-hydraulic cylinder embodies an air cylinder and a hydraulic cylinder in tandem, each fitted with a piston with a common piston rod between. The air piston is of greater diameter than the hydraulic piston. This difference in areas of the two pistons gives a resultant hydraulic pressure much greater than the air pressure admitted to the air cylinder. Automatic valves, operated by fluid pressure from the master cylinder, control the air admitted to the air cylinder. Thus, the fluid pressure in the brake lines is always in a direct ratio to foot pressure on the brake pedal.

Valve action varies with the amount of brake pedal pressure. When heavy brake pedal pressure is applied by the operator for hard braking, the hydraulic pressure in the master cylinder (which operates the valves) causes greater valve movement, and therefore the valves admit more air pressure into the air-hydraulic cylinder. This higher air pressure causes a stronger braking action. With only a light brake pedal pressure, the valves admit less air pressure into the air-hydraulic cylinder and the braking action is lighter.


TO WINDSHIELD WIPERS
COMPRESSOR
TO AIR HORN
AIR LINES
HYDRAULIC LINES
DUMMY COUPLING
CUT-OUT COCK
HOSE COUPLING
EMERGENCY LINE TO TRAILER CONNECTION
GOVERNOR
TO FRONT WHEEL BRAKES
BRAKE PEDAL
MASTER CYLINDER
AIR-HYDRAULIC CYLINDER
SAFETY VALVE
TO REAR WHEEL BRAKES
CUT-OUT COCK
HOSE COUPLING
RESERVOIR
LOW PRESSURE INDICATOR
AIR SUPPLY VALVE
DRAIN VALVE
DUMMY COUPLING
SERVICE LINE TO TRAILER CONNECTION

FP. 47

Figure 4-12.—Air-hydraulic brake system.

CHAPTER 5

FLUID LINES AND CONNECTORS

The control and application of fluid power would be impossible without a suitable means of conveying the fluid from the power source to the point of application. Fluid lines used for this purpose must be designed and installed with the same care applicable to the other components of the system. An improperly piped system can lead to serious power loss and/or harmful fluid contamination. Therefore, the lines and connectors of fluid power systems are designed with several basic requirements in mind. The following is a list of some of the most important requirements which must be considered:

1. The lines must be of sufficient strength to contain the fluid at the required pressure and, in addition, must be strong enough to withstand the surges of pressure that may develop in the system during any portion of the operating cycle.

2. The lines must be of sufficient strength to support components which may be mounted in or on them.

3. Terminal fittings (flanges, unions, etc.) must be provided at all junctions with parts or components that require removal or replacement.

4. Line supports must be capable of damping shock waves caused by surges of pressure and changes in direction of flow.

5. The lines should have a smooth interior surface to reduce turbulent flow of fluid.

6. The lines must be of the correct size to insure the required volume and velocity of flow with the least amount of turbulence during all demands of the system. Lines which provide return flow in hydraulic systems must be large enough so as not to build up excessive back pressure.

7. The interior surface of the fluid lines must be clean upon installation. After installation, lines must be kept clean by flushing or purging the system regularly. Any source of contaminant must be eliminated.

To obtain these required results, attention must be given to the various types, materials, and sizes of lines available for fluid power systems. The different types of lines and their application to fluid power systems are described in the first part of this chapter. The last part of the chapter is devoted to the various connectors applicable to the different types of fluid lines.

TYPES OF FLUID LINES

The three most common types of lines used in fluid power systems are pipe, tubing, and flexible hose. They are sometimes referred to as rigid, semirigid, and flexible. A number of factors are considered when selecting the type of lines for a particular fluid power system. These factors include the type of fluid medium, required pressure of the system, and the location of the system. For example, heavy pipe might be used for a large stationary fluid power system, but comparatively lightweight tubing must be used in aircraft and missile systems because weight and space are critical factors. Flexible hose is required in some installations where units must be free to move relative to each other.

PIPE AND TUBING

In commercial usage, there is no clear distinction between pipe and tubing, since the correct designation for each tubular product is established by the manufacturer. If the manufacturer calls a product pipe, it is pipe; if he calls it tubing, it is tubing.

In the Navy, however, a distinction is made between pipe and tubing. This distinction is based on the method the tubular product is identified as to size.

Size

There are three important dimensions of any tubular product—outside diameter (OD), inside diameter (ID), and wall thickness. A tubular product is called tubing if its size is identified by actual measured outside diameter and by actual wall thickness. A tubular product is called pipe if its size is identified by a nominal dimension and wall thickness.

In the past, wall thickness of pipe was classified as standard (Std), extra strong (XS), and double extra strong (XXS). These designations are still used to some extent. However, pipe is manufactured in a number of different wall thicknesses and does not always fit into the standard, extra strong, and double extra strong classifications. In recent years, a trend has developed toward the use of scheduled numbers to classify the wall thickness of pipe and pipe fittings. These scheduled numbers, established by the American Standards Association, range from 10 to 160 and cover 10 distinct sets of wall thickness. (See table 5-1.) Schedules 40 and 80 are comparable in wall thickness for most nominal pipe sizes to the standard and extra strong class, respectively. Schedule 160 covers pipe with the greatest wall thicknesses in this classification, but are slightly thinner than the double extra strong class. The table includes only pipe sizes up through 12-inch nominal size, although larger pipe sizes are available. Schedule 10 is for nominal pipe sizes larger than 12 inches.

A nominal dimension is close to—but not necessarily identical with—an actual measured dimension. As indicated in table 5-1, a pipe with a nominal size of 3 inches has an actual measured outside diameter of 3.500 inches. A pipe with a nominal size of 2 inches has an actual measured outside diameter of 2.375 inches. In the larger size (above 12 inches), the nominal pipe size and the actual measured outside diameter are the same. For example, a pipe with a nominal pipe size of 14 inches has an actual measured outside diameter of 14 inches. Nominal dimensions are used in order to simplify the standardization of pipe fittings, pipe taps, and threading dies.

The wall thickness of pipe increases as the schedule numbers increase. For example, a reference to schedule 40 for a pipe with a nominal pipe size of 3 inches indicates that the wall thickness is $0.216\left(\frac{3.500 - 3.068}{2}\right)$. (NOTE: The difference between the outside diameter and the inside diameter includes two wall thicknesses; therefore, this difference must be divided by 2 to obtain the wall thickness.) A reference to schedule 80 for a pipe of the same nominal size (3 inches) indicates that the wall thickness is 0.300 inch.

Tubing differs from pipe in its size classification. Tubing is designated by its actual outside diameter. (See table 5-2.) Thus, 5/8-inch tubing has an outside diameter of 5/8 inch. As indicated in the table, tubing is available in a variety of wall thicknesses. The diameter of tubing is often measured and indicated in 16ths. Thus, No. 6 tubing is 6/16 or 3/8 inch, No. 8 tubing is 8/16 or 1/2, etc.

The foregoing is a brief description of the standard ways to identify the size and wall thickness of pipe and tubing. It should be noted, however, that pipe and tubing are sometimes identified in other ways. For example, some tubing is identified by ID rather than by OD and some pipe is identified by nominal pipe size, by OD, by ID, and by actual measured wall thickness.

Materials

The pipe and tubing used in fluid power systems are commonly made from steel, copper, brass, aluminum, and stainless steel. Each of these has their own distinct advantages or disadvantages in certain applications.

Steel pipe and tubing are relatively inexpensive, and are used in many hydraulic and pneumatic systems. Steel is used because of its strength, its suitability for bending and flanging, and its adaptability to high pressures and temperatures. Its chief disadvantage is its comparatively low resistance to corrosion.

Copper pipe and tubing are sometimes used for fluid power lines. Copper has high resistance to corrosion and is easily drawn or bent. It is unsatisfactory for high temperatures and has a tendency to harden and break due to stress and vibration.

Aluminum has many of the characteristics and qualities required for fluid power lines.

Table 5-1. —Wall thickness schedule designations for pipe.

Nominal size	Pipe OD	Inside diameter									
		Sched. 10	Sched. 20	Sched. 30	Sched. 40	Sched. 60	Sched. 80	Sched. 100	Sched. 120	Sched. 140	Sched. 160
1/8	0.405				0.269		0.215				
1/4	.540				.364		.302				
3/8	.675				.493		.423				
1/2	.840				.622		.546				0.466
3/4	1.050				.824		.742				.614
1	1.315				1.049		.957				.815
1 1/4	1.660				1.380		1.278				1.160
1 1/2	1.900				1.610		1.500				1.338
2	2.375				2.067		1.939				1.689
2 1/2	2.875				2.469		2.323				2.125
3	3.500				3.068		2.900				2.624
3 1/2	4.000				3.548		3.364				
4	4.500				4.026		3.826		3.624		3.438
5	5.563				5.047		4.813		4.563		4.313
6	6.625				6.065		5.761		5.501		5.189
8	8.625		8.125	8.071	7.981	7.813	7.625	7.439	7.189	7.001	6.813
10	10.750		10.250	10.136	10.020	9.750	9.564	9.314	9.064	8.750	8.500
12	12.750		12.250	12.090	11.934	11.626	11.376	11.064	10.750	10.500	10.126

It has high resistance to corrosion and is easily drawn or bent. In addition, the outstanding characteristic of aluminum is its light weight. Since weight elimination is a vital factor in the design of aircraft, aluminum alloy tubing is used in the majority of aircraft fluid power systems. Two aluminum alloys are in common use—alloy 5052 may be used for lines carrying pressures up to 1,500 psi, and alloy 6061 for pressures up to 3,000 psi. Stainless steel tubing is used in certain areas of many aircraft fluid power systems. As a general rule, exposed lines and lines subject to abrasion or intense heat are made of stainless steel.

Application

The material, the inside diameter, and the wall thickness are the three primary considerations in the selection of lines for a particular fluid power system. Most of the advantages and disadvantages of the metals used for the construction of fluid power lines were covered in the preceding paragraphs.

The inside diameter of a line is important, since it determines the rate of flow that can be passed through the line without loss of power due to excessive friction and heat. Velocity of

Table 5-2. —Tubing size designation.

Tube OD	Wall thickness	Tube ID
1/8	0.028	0.069
	.032	.061
	.035	.055
3/16	0.032	0.1235
	.035	.1175
1/4	0.035	0.180
	.042	.166
	.049	.152
	.058	.134
	.065	.120
5/16	0.035	0.2425
	.042	.2285
	.049	.2145
	.058	.1965
	.065	.1825
3/8	0.035	0.305
	.042	.291
	.049	.277
	.058	.259
	.065	.245
1/2	0.035	0.430
	.042	.416
	.049	.402
	.058	.384
	.065	.370
	.072	.356
	.083	.334
	.095	.310
5/8	0.035	0.555
	.042	.541
	.049	.527
	.058	.509
	.065	.495
	.072	.481
	.083	.459
	.095	.435
3/4	0.049	0.652
	.058	.634
	.065	.620
	.072	.606
	.083	.584
	.095	.560
	.109	.532
7/8	0.049	0.777
	.058	.759
	.065	.745
	.072	.731
	.083	.709
	.095	.685
	.109	.657
1	0.049	0.902
	.058	.884
	.065	.870
	.072	.856
	.083	.834
	.095	.810
	.109	.782
	.120	.760
1 1/4	0.049	1.152
	.058	1.134
	.065	1.120
	.072	1.106
	.083	1.084
	.095	1.060
	.109	1.032
	.120	1.010
1 1/2	0.065	1.370
	.072	1.356
	.083	1.334
	.095	1.310
	.109	1.282
	.120	1.260
	.134	1.232
1 3/4	0.065	1.620
	.072	1.606
	.083	1.584
	.095	1.560
	.109	1.532
	.120	1.510
	.134	1.482
2	0.065	1.870
	.072	1.856
	.083	1.834
	.095	1.810
	.109	1.782
	.120	1.760
	.134	1.732

a given flow is less through a large opening than through a small opening. If the inside diameter of the line is too small for the amount of flow, excessive turbulence and friction heat cause unnecessary power loss and overheated fluid.

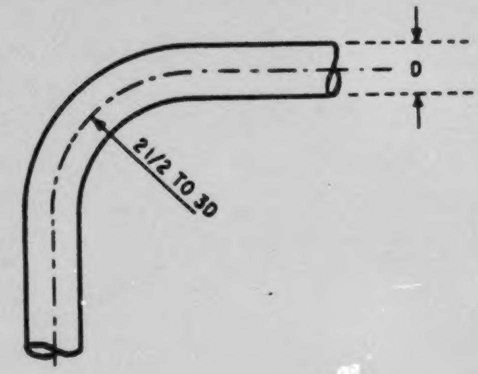
The wall thickness, the material used, and the inside diameter determine the bursting pressure of a line or fitting. The greater the wall thickness in relation to the inside diameter and the stronger the metal, the higher the bursting pressure. However, the greater the inside diameter for a given wall thickness, the lower the bursting pressure, because force is the product of area and pressure. Industrial activities recommend that rigid lines should have a bursting pressure which provides a safety factor of at least eight; that is, the rated bursting pressure should be at least eight times greater than the maximum working pressure in the system.

The manufacturers of pipe and tubing usually supply charts, graphs, or tables which aid in the selection of the proper lines for fluid power systems. These tables and charts use different methods of deriving the correct sizes of pipe and tubing. Regardless of the method, some provision must be made for correlating the strength of the line in terms of bursting pressure with the inside diameter in terms of flow capacity at recommended velocity.

Fluid power systems are designed as compactly as practicable, in order to keep the connecting lines short. Every section of line should be anchored securely in one or more places so that neither the weight of the line nor the effects of vibration are carried on the joints. The aim should be to minimize stress throughout.

Lines should normally be kept as short and free of bends as possible. However, tubing should not be assembled in a straight line, because a bend tends to eliminate strain by absorbing vibration and also compensates for thermal expansion and contraction. Bends are preferred to elbows, because bends cause less of a power loss. A few of the correct and incorrect methods of installing tubing are illustrated in figure 5-1.

Bends are described in terms of the ratio of the radius of the bend to the inside diameter of the tubing or pipe. The ideal bend radius is 2 1/2 to 3 times the inside diameter, as shown in figure 5-2. For example, if the inside diameter of a line is 2 inches, the radius of the bend should be between 5 and 6 inches.



FP.49

Figure 5-2.—Ideal bend radius.

While friction head increases markedly for sharper curves than this, it also tends to increase up to a certain point for gentler curves. The increases in friction in a bend with a radius of more than about 3 pipe diameters result from increased turbulence near the outside edges of the flow. Particles of fluid must travel a longer distance in making the change in direction. When the radius of the bend is less than about 2 1/2 pipe diameters, the increased pressure loss is due to the abrupt change in the direction of flow, especially for particles near the inside edge of the flow.

Cutting and bending of pipe and tubing are covered in Basic Handtools, NavPers 10085 (Series), in other applicable Rate Training Manuals, and in applicable technical publications.

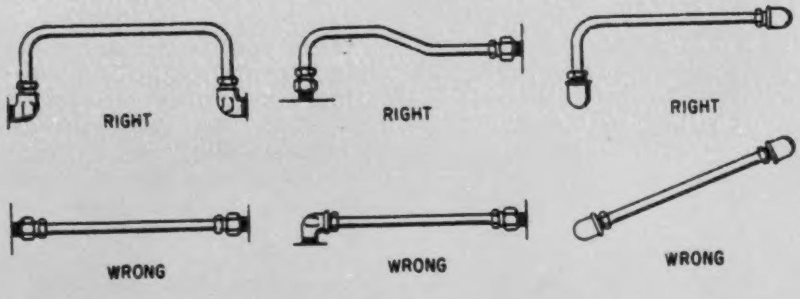


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Figure 5-1.—Correct and incorrect methods of installing tubing.

FLEXIBLE HOSE

Hose is used in fluid power systems where there is a necessity for flexibility, such as connections to actuating units that move while in operation, or to units attached to a hinged portion of the equipment. It is also used in locations that are subjected to severe vibrations. For example, flexible hose is often used for connections to and from the pump. The vibration that is set up by an operating pump would ultimately cause rigid and semirigid lines to fail.

Sizes

The size of flexible hose is identified by a number which refers to the equivalent tubing size; for example, No. 8 flexible hose is equivalent to No. 8 tubing. The No. 8 tubing has an outside diameter of 1/2 inch (8/16). The inside diameter of No. 8 hose will not be 1/2 inch; it will be slightly smaller to allow for wall thickness. The actual inside diameter of both the hose and tubing is the same. As long as the number of the hose corresponds to the number of the tubing, the proper size is being used.

The size, along with other information, is usually stenciled on the outside of the hose. This information includes the Military Specification of the hose followed by a dash number, which is the size. In addition, the year of manufacture and the manufacturer's symbol are also included. If the hose is assembled with end fittings, the length of the hose is also included. This information appears at intervals of not more than 9 inches and is connected by a series of dots or dashes. The continuous line of stenciled information and dots or dashes also indicates the natural lay of the hose. On some of the newer types of hose, such as Teflon (discussed later), this information is placed on a metal tag and attached to the hose.

Materials

In regards to material, there are two types of flexible hose used in fluid power systems. These two types of material are rubber and Teflon. Although flexible hose made of rubber is the type most commonly used, Teflon has many of the desired characteristics for certain applications. These two types of materials are described in the following paragraphs.

RUBBER.—Flexible rubber hose consists of a seamless synthetic rubber tube covered with layers of cotton braid and wire braid, and an outer layer of rubber-impregnated cotton braid. The inner tube is designed to withstand the attack of the material which passes through it. The braid, which may consist of several layers, is the determining factor in the strength of the hose. The cover is designed to withstand external abuse.

TEFLON.—Teflon hose is a flexible hose designed to meet the requirements of higher operating pressures and temperatures in present fluid power systems. This type hose consists of a chemical resin, which is processed and extruded into tube shape to a desired size. It is covered with stainless steel wire which is braided over the tube for strength and protection.

Teflon hose is unaffected by all fluids presently used in fluid power systems. It is inert to acids, both concentrated and diluted. Certain Teflon hose may be used in systems where operating temperatures range from -100° F to + 500° F. Teflon is nonflammable; however, where the possibility of open flame exists, a special asbestos fire sleeve should be used.

Teflon hose will not absorb moisture. This, together with its chemical inertness and anti-adhesive characteristics, makes it ideal for missile fluid power systems where noncontamination and cleanliness are so essential.

Application

Flexible hose is available in four pressure ranges—extra-high-pressure, high-pressure, medium-pressure, and low-pressure. Extra-high-pressure hose is used in fluid power systems with normal operating pressures in excess of 3,000 psi. High-pressure hose is used in systems with normal operating pressures up to and including 3,000 psi. Medium-pressure hose is used with a wide range of pressures (approximately 300 psi to 3,000 psi); however, it must be emphasized that the maximum operating pressure for a particular medium-pressure hose depends upon its size. For example, No. 12 hose is limited to pressures up to 1,500 psi, No. 8 hose to 2,000 psi, and No. 4 hose to 3,000 psi. The maximum operating pressure for low-pressure hose (up to approximately 600 psi) is also determined by the size of the hose. The use of low-pressure hose in fluid power systems is limited. It is used in some low-pressure pneumatic systems and as exhaust lines and drain lines in some high-pressure fluid power systems.

Extra-high-pressure hose and some high-pressure hose are available only in complete assemblies with factory installed end fittings. Some high-pressure hose is available in bulk form and can be fabricated with end fittings by certain designated activities which have the required special tools and equipment. Medium- and low-pressure hose are available in bulk and are usually fabricated locally. The fabrication of hose assemblies is covered in applicable Rate Training Manuals and technical publications.

Flexible hose must not be twisted on installation, since this reduces the life of the hose considerably and may cause the fittings to loosen as well. Twisting of the hose can be determined from the identification stripe running along its length. This stripe should not tend to spiral around the hose. (See fig. 5-3.)

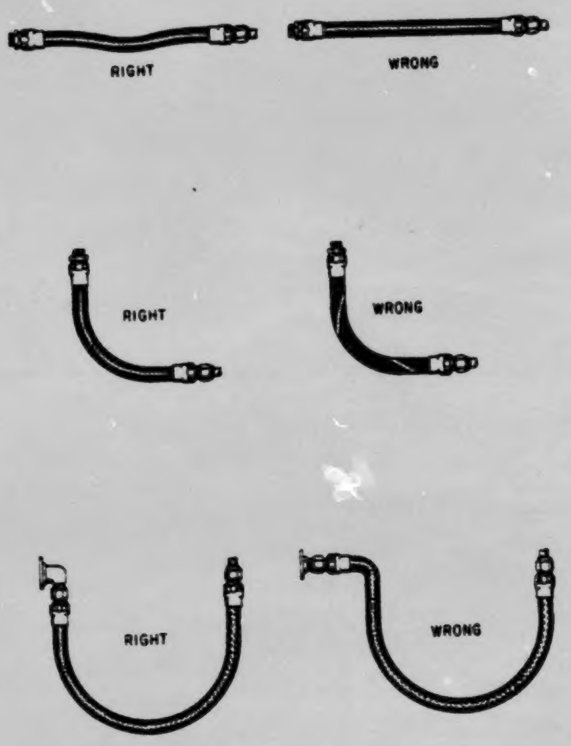


Figure 5-3.—Correct and incorrect installation of flexible hose. FP.50

Flexible hose should be protected from chafing by wrapping lightly with tape, but only where necessary.

The minimum bend radius for flexible hose varies according to size and construction of the hose and the pressure under which the system operates. Current applicable technical publications contain tables and graphs showing minimum bend radii for the different types of installations. Bends which are too sharp will reduce the bursting pressure of flexible hose considerably below its rated value.

Flexible hose should be installed so that it will be subjected to a minimum of flexing during operation. Support clamps are not necessary with short installations; but with hose of considerable length (48 inches for example), clamps should be placed not more than 24 inches apart. Closer supports are desirable and in some cases required.

A flexible hose must never be stretched tight between two fittings. About 5 to 8 percent of the total length must be allowed as slack to provide freedom of movement under pressure. When under pressure, flexible hose contracts in length and expands in diameter. Examples of correct and incorrect installations of flexible hose are illustrated in figure 5-3.

Teflon hose should be handled carefully during removal and installation. Some Teflon hose is preformed during fabrication. This type hose tends to form itself to the installed position in the system. To insure its satisfactory function and reduce the likelihood of failure, the following rules should be observed when working with Teflon hose:

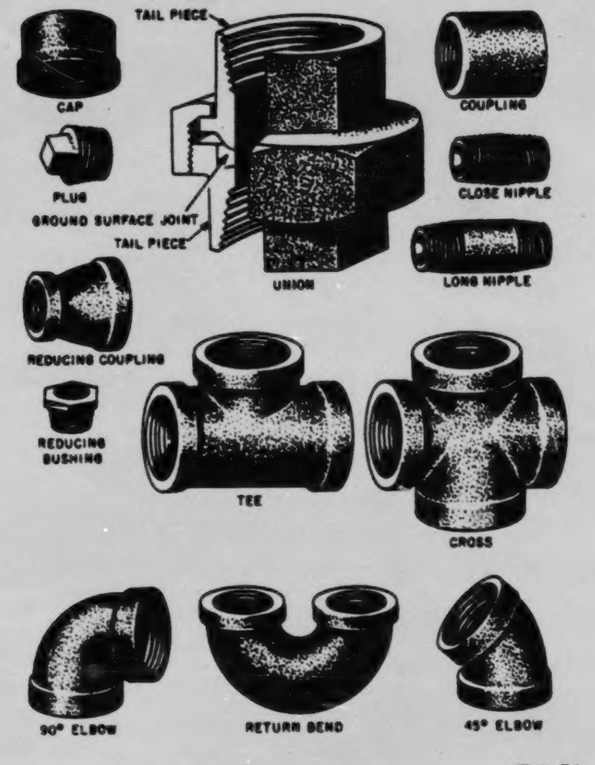
1. Do not exceed recommended bend limits.
2. Do not exceed twisting limits.
3. Do not straighten a bent hose that has taken a permanent set.
4. Do not hang, lift, or support objects from Teflon hose.

TYPES OF CONNECTORS

Some type of connector must be provided to attach the lines to the components of the system and to connect sections of line to each other. There are many different types of connectors provided for this purpose. The type of connector required for a specific system depends on several factors. One determining factor, of course, is the type of fluid line (pipe, tubing, or flexible hose) used in the system. Other determining factors are the type of fluid medium and the maximum operating pressure of the system. Some of the most common types of connectors are described in the following paragraphs.

THREADED CONNECTORS

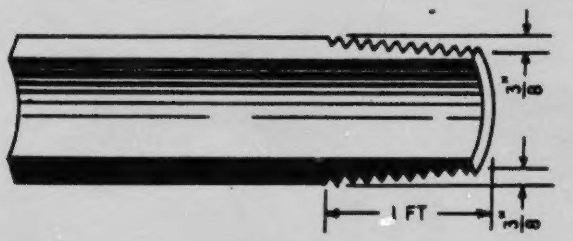
There are several different types of threaded connectors, some of which are described later. In the type discussed in this section, both the connector and the end of the fluid line (pipe) are threaded. This type connector is used in some low-pressure fluid power systems. In Navy systems, they are usually made of steel, copper, or brass, and in a variety of designs, some of which are illustrated in figure 5-4.



FP.51

Figure 5-4.—Threaded pipe connectors.

Threaded connectors are made with standard female threading cut on the inside surface. The end of the pipe is threaded with outside (male) threads for connecting. Standard pipe threads are tapered slightly to insure tight connections. The amount of taper is approximately three-fourths of an inch in diameter per foot of thread. (See fig. 5-5.)

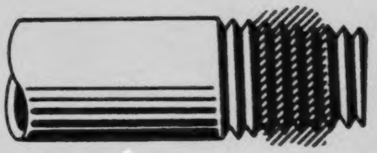


FP.52

Figure 5-5.—Standard taper for pipe threads.

Metal is removed when a pipe is threaded, thinning the pipe and exposing new and rough surfaces for chemical action. Corrosion agents work more quickly at such points than elsewhere. If pipes are assembled with no protective compound on the threads, corrosion sets in at once and the two sections stick together so that the threads seize when disassembly is attempted. The result is damaged threads and pipes.

To prevent seizing, a suitable pipe thread compound is sometimes applied to the threads as illustrated in figure 5-6. The two end threads



FP.53

Figure 5-6.—Application of protective compound to pipe threads.

are kept free of compound so that it will not contaminate the fluid. Pipe compound, when improperly applied, may get inside the lines and components and damage pumps and control equipment. This has been such a problem that many manufacturers forbid the use of any compound when fabricating the piping for fluid power systems.

Another type of material used on pipe threads is sealant tape. This tape, which is made of Teflon, provides an effective means of sealing pipe connections and eliminates the necessity of torquing connections to excessively high values in order to prevent pressure leaks. It also provides for ease of maintenance whenever it is necessary to disconnect pipe joints. The tape is applied over the male threads, leaving the first thread exposed. After the tape is pressed firmly against the threads, the joint is connected.

FLANGE CONNECTORS

Bolted flange connectors (fig. 5-7) are suitable for most pressures now in use. The flanges are attached to the piping by welding, brazing, tapered threads (for some low-pressure systems), or rolling and bending into recesses. Those illustrated are the most common types of flange joints used. The same types of standard fitting shapes (tee, cross, elbow, etc.) are manufactured for flange joints, such as the threaded connectors illustrated in figure 5-4. Suitable gasket material must be used between the flanges.

WELDED CONNECTORS

The subassemblies of some fluid power systems are connected by welded joints, especially in high-pressure systems which utilize pipe for fluid lines. The welding is accomplished according to standard specifications which define the materials and techniques. There are three general classes of welded joints—butt-weld, fillet-weld, and socket-weld. (See fig. 5-8.)

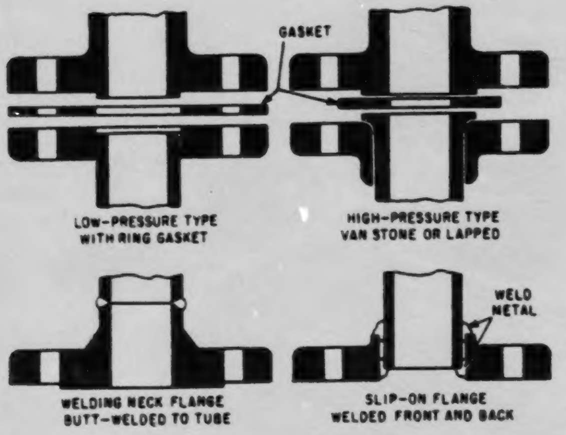

GASKET
LOW-PRESSURE TYPE WITH RING GASKET
HIGH-PRESSURE TYPE VAN STONE OR LAPPED
WELD METAL
WELDING NECK FLANGE BUTT-WELDED TO TUBE
SLIP-ON FLANGE WELDED FRONT AND BACK
FP.54

Figure 5-7.—Four types of bolted flange connectors.

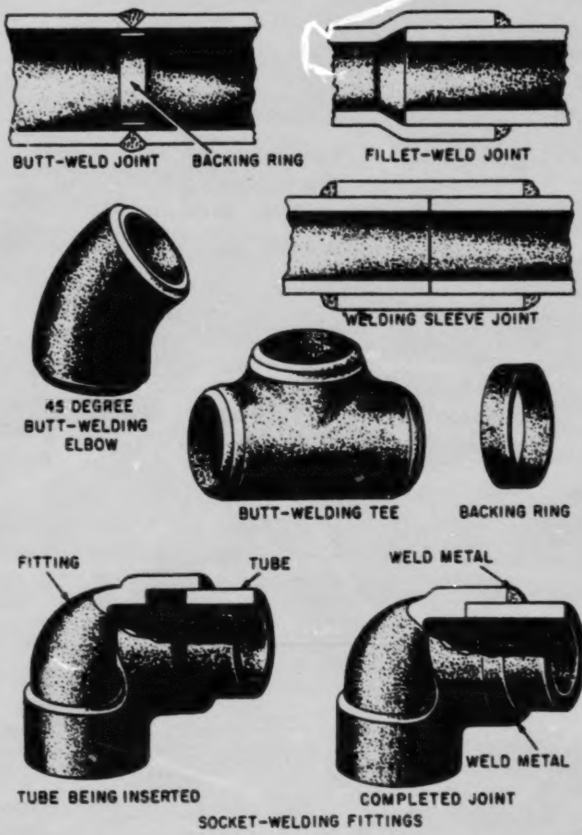
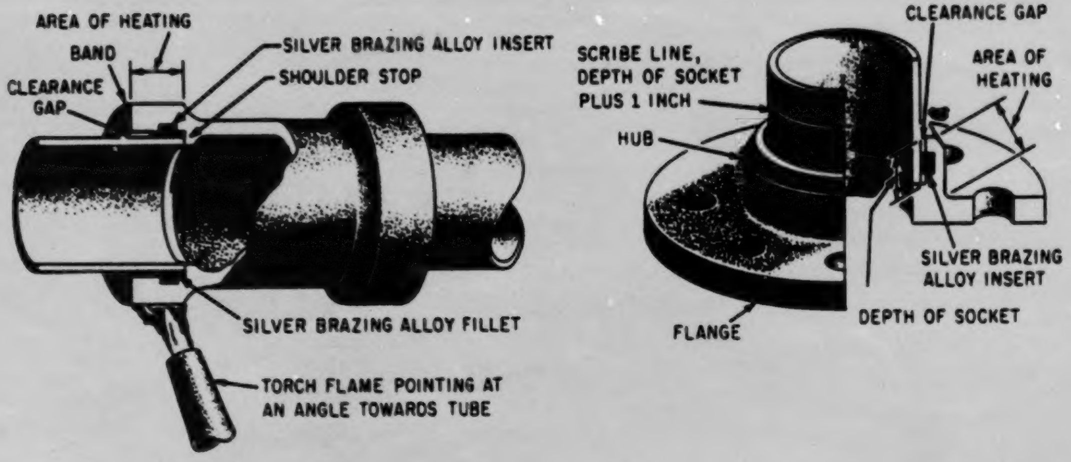

BUTT-WELD JOINT
BACKING RING
FILLET-WELD JOINT
WELDING SLEEVE JOINT
45 DEGREE BUTT-WELDING ELBOW
BUTT-WELDING TEE
BACKING RING
FITTING
TUBE
WELD METAL
WELD METAL
TUBE BEING INSERTED
COMPLETED JOINT
SOCKET-WELDING FITTINGS
FP.55

Figure 5-8.—Various types of welded joints.


AREA OF HEATING
BAND
CLEARANCE GAP
SILVER BRAZING ALLOY INSERT
SHOULDER STOP
SILVER BRAZING ALLOY FILLET
TORCH FLAME POINTING AT AN ANGLE TOWARDS TUBE
SCRIBE LINE, DEPTH OF SOCKET PLUS 1 INCH
HUB
CLEARANCE GAP
AREA OF HEATING
SILVER BRAZING ALLOY INSERT
DEPTH OF SOCKET
FLANGE

FP.56

Figure 5-9.—Silver-brazed connectors.

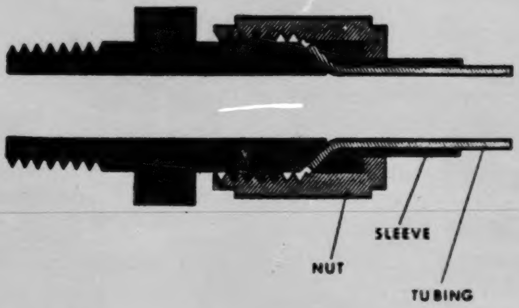
BRAZED CONNECTORS

Silver-brazed connectors (fig. 5-9) are commonly used for joining nonferrous (copper, brass, etc.) piping in the pressure and temperature range where their use is practical. These practical factors limit the use of this type connector to lines not exceeding 425° F; for cold lines, these fittings may be used for pressures up to 3,000 psi. The alloy is melted by heating the joint with an oxyacetylene torch. This causes the alloy insert to melt and fill the few thousandths of an inch annular space between the pipe and the fitting.

A fitting of this type which has been removed from a piping system can be rebrazed into a system, as in most cases sufficient alloy remains in the insert groove for a second joint. New alloy inserts may be obtained for fittings which do not have sufficient alloy remaining in the insert for making a new joint.

FLARED CONNECTORS

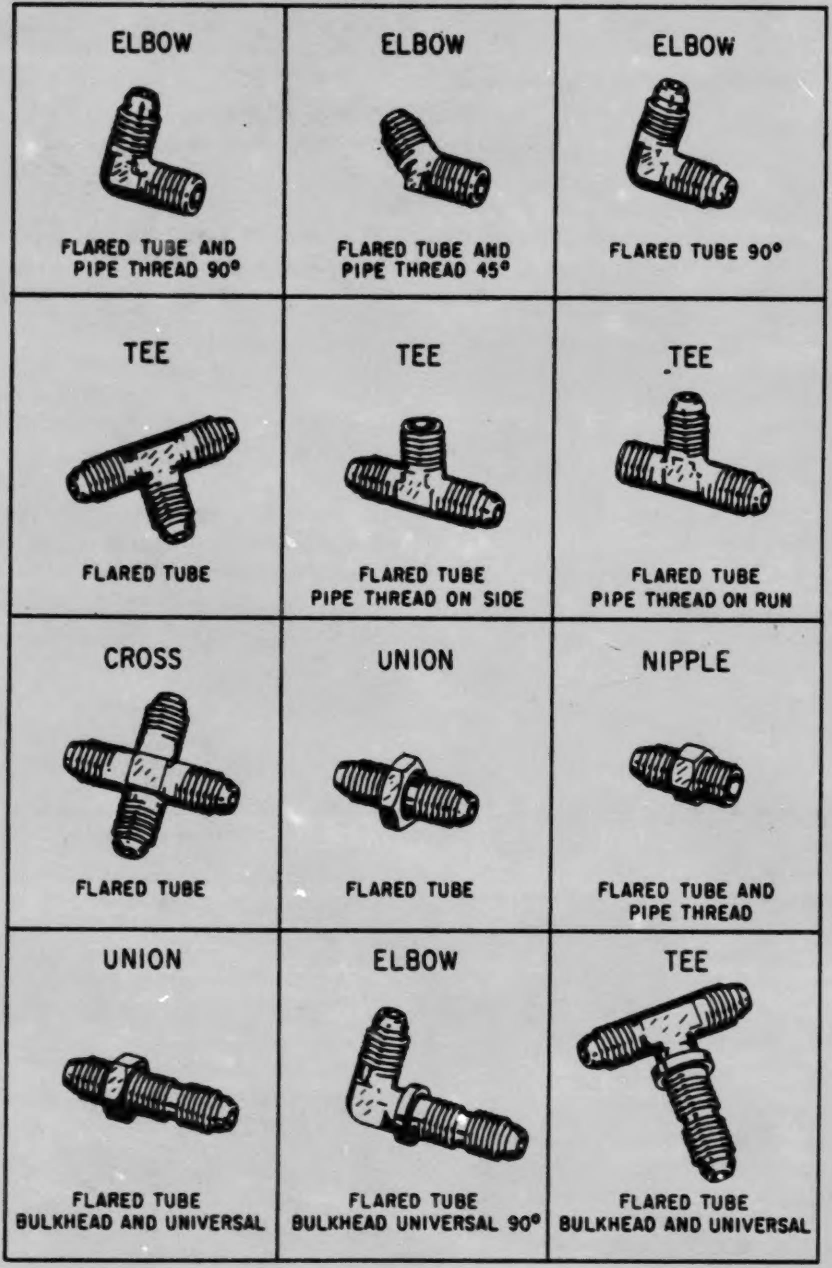
Flared connectors are commonly used in fluid power systems containing lines made of tubing. These connectors provide safe, strong, dependable connections without the necessity of threading, welding, or soldering the tubing. The connector consists of a fitting, a sleeve, and a nut, as illustrated in figure 5-10.


SLEEVE
NUT
TUBING

FP.57

Figure 5-10.—Flared-tube connector.

The fittings are made of steel, aluminum alloy, or bronze. The fittings should be of the same material as that of the sleeve, nut, and tubing. For example, use steel connectors with steel tubing and aluminum alloy connectors with aluminum alloy tubing. Fittings are made in unions, 45-degree and 90-degree elbows, tees, and various other shapes. Figure 5-11

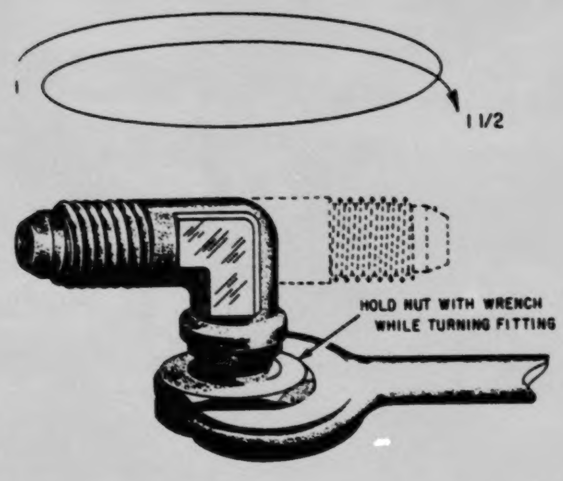

ELBOW
FLARED TUBE AND PIPE THREAD 90°
ELBOW
FLARED TUBE AND PIPE THREAD 45°
ELBOW
FLARED TUBE 90°
TEE
FLARED TUBE
TEE
FLARED TUBE PIPE THREAD ON SIDE
TEE
FLARED TUBE PIPE THREAD ON RUN
CROSS
FLARED TUBE
UNION
FLARED TUBE
NIPPLE
FLARED TUBE AND PIPE THREAD
UNION
FLARED TUBE BULKHEAD AND UNIVERSAL
ELBOW
FLARED TUBE BULKHEAD UNIVERSAL 90°
TEE
FLARED TUBE BULKHEAD AND UNIVERSAL

FP.58

Figure 5-11.—Flared-tube fittings.

illustrates some of the most common fittings used with flared connectors.

Tees, crosses, and elbows are self-explanatory. Universal and bulkhead fittings can be mounted solidly with one outlet of the fitting extending through a bulkhead and the other outlet (s) positioned at any angle. Universal denotes the fact that the fitting can assume the angle required for the specific installation. Bulkhead denotes that the fitting is long enough to pass through a bulkhead and is designed in such a manner that it can be secured solidly to the bulkhead. Figure 5-12 illustrates a universal bulkhead-mounted fitting.


1
1 1/2
HOLD NUT WITH WRENCH
WHILE TURNING FITTING

FP.59

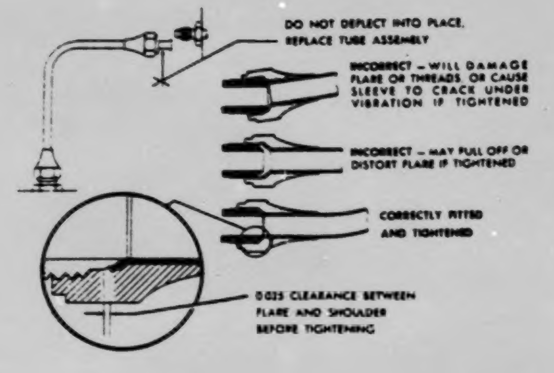
Figure 5-12.—Universal bulkhead-mounted fitting.

For connecting to tubing, the ends of the fittings are threaded with straight machine threads to correspond with the female threads of the nut. In some cases, however, one end of the fitting may be threaded with tapered pipe threads to fit threaded ports in pumps, valves, and other components. Several of these thread combinations are shown in figure 5-11. For example, unions have straight machine threads on both ends, while elbows have straight machine threads on one end, but may have either tapered pipe threads or straight machine threads on the other end. Tees and crosses also are available in several different combinations.

Tubing used with this type connector must be flared prior to assembly. The nut fits over the sleeve and when tightened, draws the sleeve and tubing flare tightly against the male fitting to form a seal.

The male fitting has a cone-shaped surface with the same angle as the inside of the flare. The sleeve supports the tube so that vibration does not concentrate at the edge of the flare, and distributes the shearing action over a wider area for added strength. Tube flaring is covered in Basic Handtools, NavPers 10085 (Series), and other applicable Rate Training Manuals.

Correct and incorrect methods of installing flared-tube connectors are illustrated in figure 5-13. Tubing nuts should be tightened with a torque wrench to the value specified in applicable technical publications.


DO NOT DEFLECT INTO PLACE.
REPLACE TUBE ASSEMBLY
INCORRECT – WILL DAMAGE FLARE OR THREADS, OR CAUSE SLEEVE TO CRACK UNDER VIBRATION IF TIGHTENED
INCORRECT – MAY PULL OFF OR DISTORT FLARE IF TIGHTENED
CORRECTLY FITTED AND TIGHTENED
.0025 CLEARANCE BETWEEN FLARE AND SHOULDER BEFORE TIGHTENING

FP.60

Figure 5-13.—Correct and incorrect methods of tightening flared connectors.

If an aluminum alloy flared connector leaks after tightening to the required torque, it must not be tightened further. Overtightening may severely damage or completely cut off the tubing flare or may result in damage to the sleeve or nut. The leaking connection must be disassembled and the fault corrected.

If a steel tube connection leaks, it may be tightened 1/6 turn beyond the specified torque in an attempt to stop the leakage; then if unsuccessful, it must be disassembled and repaired.

Some of the causes of leaking flared connectors are as follows:

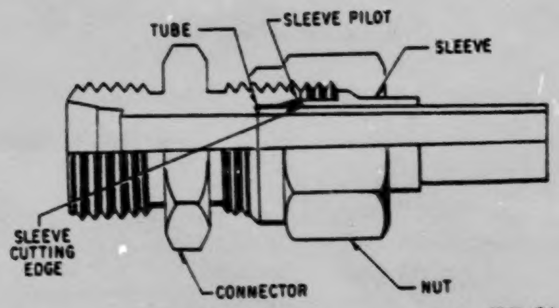
1. Flare distorted into nut threads.
2. Sleeve cracked.
3. Flare cracked or split.
4. Flare out of round.
5. Flare eccentric to tube OD.
6. Inside of flare rough or scratched.
7. Fitting cone rough or scratched.
8. Threads of the fitting or nut dirty, damaged, or broken.

Undertightening of connections may be serious, as this can allow the tubing to leak at the connector because of insufficient grip on the flare by the sleeve. The use of a torque wrench will prevent undertightening.

CAUTION: A nut should never be tightened when there is pressure in the line, as this will tend to damage the connection without adding any appreciable torque to the connection.

BITE TYPE CONNECTORS

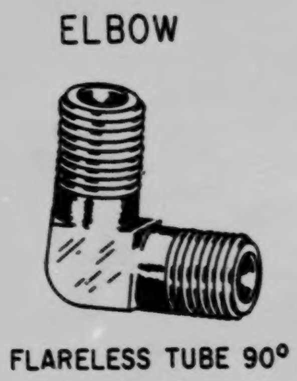
Bite type connectors are commonly referred to as flareless-tube connectors. This type connector eliminates all tube flaring, yet provides a safe, strong, and dependable tube connection. This connector consists of a fitting, a sleeve or ferrule, and a nut. (See fig. 5-14.)



FP.61

Figure 5-14.—Flareless-tube connector.

Flareless-tube fittings are available in many of the same shapes and thread combinations as flared-tube fittings. (See fig. 5-11.) An example of a flareless-tube fitting is illustrated in figure 5-15. The fitting has a counterbore shoulder for the end of the tubing to rest against. The angle of the counterbore causes the cutting edge of the sleeve or ferrule to cut into the outside surface of the tube when the two are assembled together.



FP.62

Figure 5-15.—Flareless-tube fitting.

The nut presses on the bevel of the sleeve and causes it to clamp tightly to the tube. Resistance to vibration is concentrated at this point rather than at the sleeve cut. When fully tightened, the sleeve or ferrule is bowed slightly at the midsection and acts as a spring. This spring action of the sleeve or ferrule maintains a constant tension between the body and the nut and thus prevents the nut from loosening.

Prior to the installation of a new flareless-tube connector, the end of the tubing must be square, concentric, and free of burrs. For the connection to be effective, the cutting edge of the sleeve or ferrule must bite into the periphery of the tube. This is accomplished by presetting the sleeve or ferrule on the tube using a presetting tool which has the same dimensions as the fitting body, and which can be obtained from the fitting manufacturer. If a presetting tool is not available, a suitable male-thread fitting may be used. If a fitting must be used, a steel fitting is preferred for this operation. If an aluminum fitting is used as a preset tool, it should not be reused in the system.

Applicable Rate Training Manuals, technical publications, or specifications may be consulted for the proper procedures to be followed for presetting flareless-tube connectors.

After presetting, the connector is disassembled for inspection. If the sleeve or ferrule is satisfactorily installed, the connector is ready for final assembly in the system. When making the final assembly in the system, the following installation procedures should be followed:

1. Lubricate all threads with a liquid that is compatible with the fluid that is to be used in the system.

2. Place the tube assembly in position and check for alignment.

3. Tighten the nut by hand until an increase in resistance to turning is encountered. This indicates that the sleeve or ferrule pilot has contacted the fitting.

4. If possible, use a torque wrench to tighten flareless tubing nuts. Torque values for specific installations are usually listed in the applicable technical publications. If it is not possible to use a torque wrench, use the following procedures for tightening nuts.

After the nut is handtight, turn the nut 1/6 turn (one flat on a hex nut) with a wrench. Use a wrench on the connector to prevent it from turning while tightening the nut. After the tube assembly is installed, the system should be pressure tested. Should a connection leak, it is permissible to tighten the nut an additional 1/6 turn (making a total of 1/3 turn). If, after tightening the nut a total of 1/3 turn, leakage still exists, the assembly should be removed and the components of the assembly inspected for scores, cracks, presence of foreign material, or damage from overtightening.

NOTE: Overtightening a flareless-tube nut drives the cutting edge of the sleeve or ferrule deeply into the tube, causing the tube to be weakened to the point where normal vibration could cause the tube to shear. After inspection (if no discrepancies are found), reassemble the connection and repeat the pressure test procedures.

CAUTION: Do not in any case tighten the nut beyond 1/3 turn (two flats on the hex nut); this is the maximum the fitting may be tightened without the possibility of permanently damaging the sleeve or the tube.

CONNECTORS FOR FLEXIBLE HOSE

As previously stated, extra-high-pressure and some high-pressure flexible hose are available only in complete assemblies with factory installed end fittings. The procedures involved in the fabrication of low-, medium-, and high-pressure hose are contained in applicable Rate Training Manuals and in applicable technical publications.

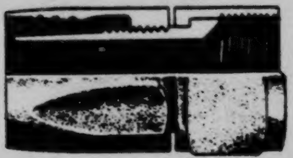
The end fittings most commonly used on flexible hose used in fluid power systems are either for the flared or flareless type connectors. Hose is also available with fittings adaptable to flange type connectors. Examples of end fittings for flexible hose are illustrated in figure 5-16.

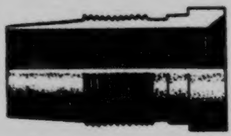
QUICK-DISCONNECT COUPLINGS

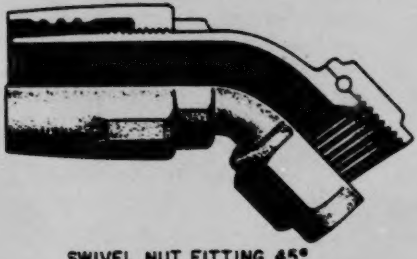
Quick-disconnect couplings of the self-sealing type are used at various points in many fluid power systems. These couplings are installed at locations where frequent uncoupling of the lines is required for inspection, test, and maintenance. Quick-disconnect couplings are also commonly used in pneumatic systems to connect sections of air hose together and to connect tools to the air pressure lines. This provides a convenient method of attaching and detaching tools and sections of lines without losing pressure.

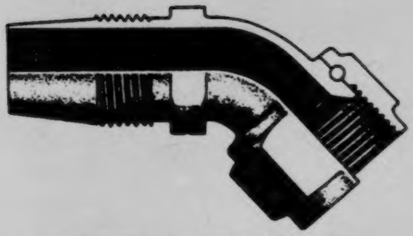
Quick-disconnect couplings provide a means of quickly disconnecting a line without the loss of fluid from the system or entrance of foreign matter into the system. Several types of quick-disconnect couplings have been designed for use in fluid power systems. Figure 5-17 illustrates a coupling that is used with portable pneumatic tools. The male section is connected to the tool or to the line leading from the tool. The female section, which contains the shutoff valve, is installed in the pneumatic line leading from the power source. These connectors can be separated or connected by very little effort on the part of the operator.

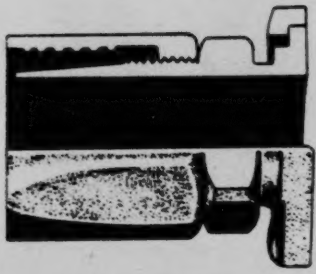
The most common quick-disconnect coupling for hydraulic systems consists of two parts, held together by a union nut. Each part contains

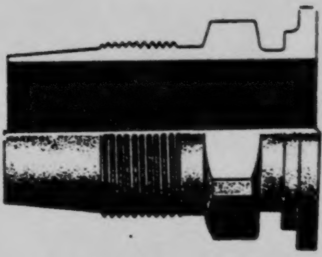

SWIVEL NUT FITTING

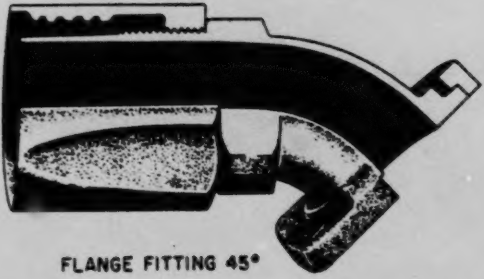

SWIVEL NUT FITTING NIPPLE

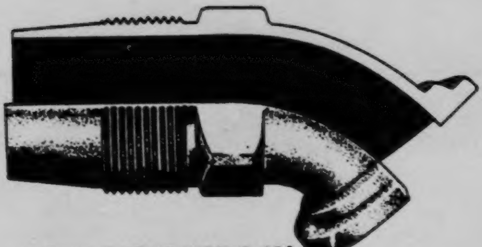

SWIVEL NUT FITTING 45°


SWIVEL NUT FITTING NIPPLE 45°


FLANGE FITTING


FLANGE FITTING NIPPLE

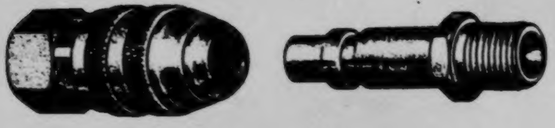

FLANGE FITTING 45°


FLANGE FITTING NIPPLE 45°

FP.63

Figure 5-16.—Flexible hose end fittings.

a valve which is held open when the coupling is connected, allowing fluid to flow in either direction through the coupling. When the coupling is disconnected, a spring in each part closes the valve, preventing the loss of fluid and entrance of foreign matter.

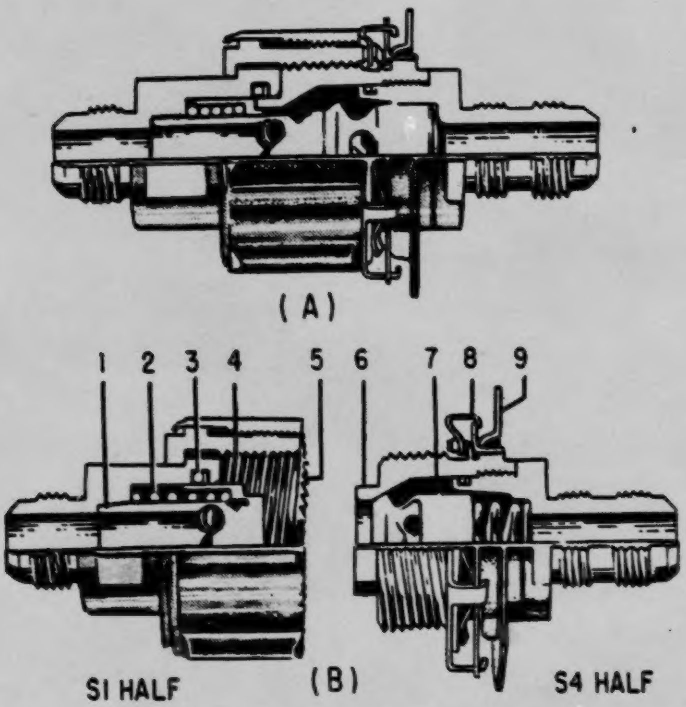


FP.64

Figure 5-17.—Quick-disconnect coupling for air lines.

The union nut has a quick-lead thread which permits connecting or disconnecting the coupling by turning the nut. The amount the nut must be turned varies with different styles of couplings. For one style, a quarter turn of the union nut locks or unlocks the coupling. For another style, a full turn is required. Some couplings require wrench tightening; others may be connected and disconnected by hand. Some installations require that the coupling be safetied with safety wire, others do not require any form of safetying. Because of these individual differences, all quick-disconnects should be installed in accordance with the instructions in the applicable technical publications.

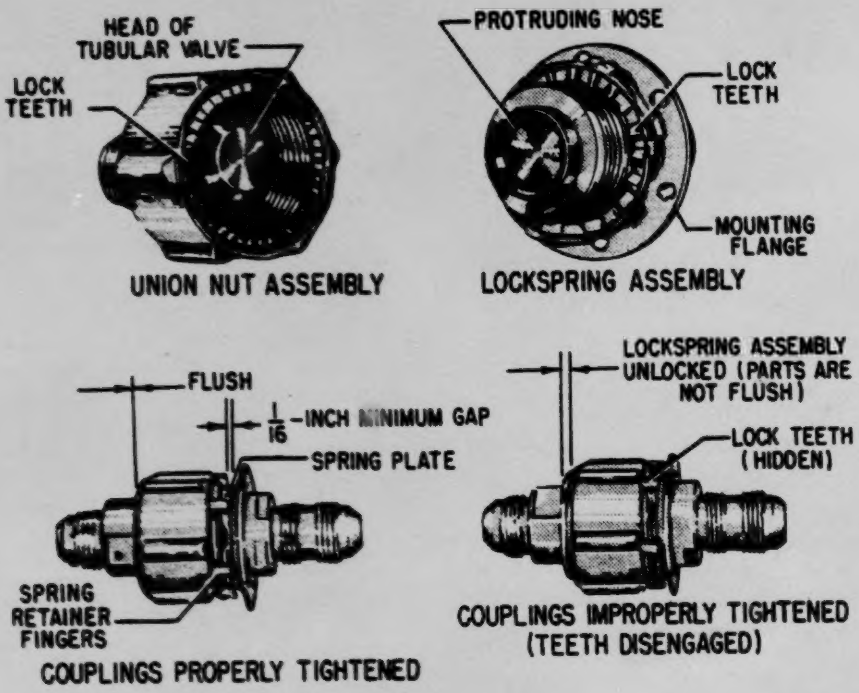
One type of quick-disconnect coupling for hydraulic systems is illustrated in figure 5-18



1. Tubular valve.
2. Valve spring.
3. O-ring packing.
4. Sleeve.
5. Union nut teeth.
6. Protruding nose.
7. Poppet valve.
8. Lock spring.
9. Mounting flange.

FP.65

Figure 5-18.—Typical quick-disconnect coupling.


HEAD OF TUBULAR VALVE
LOCK TEETH
UNION NUT ASSEMBLY
PROTRUDING NOSE
LOCK TEETH
MOUNTING FLANGE
LOCKSPRING ASSEMBLY
FLUSH
1/16-INCH MINIMUM GAP
SPRING PLATE
SPRING RETAINER FINGERS
COUPLINGS PROPERLY TIGHTENED
LOCKSPRING ASSEMBLY UNLOCKED (PARTS ARE NOT FLUSH)
LOCK TEETH (HIDDEN)
COUPLINGS IMPROPERLY TIGHTENED (TEETH DISENGAGED)

FP.66

Figure 5-19.—Quick-disconnect coupling properly and improperly tightened.

Each coupling consists of two halves, referred to as the S1 half and the S4 half. When disconnected, the union nut remains with the S1 half. The S4 half has a mounting flange (9) for attaching to a bulkhead or other structural member.

All parts referred to in the following discussion are identified in figure 5-18. The two halves of the coupling may be connected by placing the tubular valve (1) within the protruding nose (6) of the mating half and rotating the union nut in a clockwise direction. The union nut must be rotated until the teeth (5) fully engage the lock spring (8). A properly tightened coupling will have compressed the lock spring until a 1/16-inch minimum gap exists between the inside lip of the spring retainer fingers and the spring plate. Figure 5-19 shows the coupling both properly tightened and improperly tightened.

The locking action may be followed by referring to figure 5-18. Positive locking is assured by the locking spring (8) with teeth which engage the ratchet teeth on the union nut (5) when the coupling is fully connected. The lock spring automatically disengages when the union nut is unscrewed. An O-ring packing (3) seals against leakage as the coupling halves are joined. Positive opening of the valves occurs as the halves are connected.

When the coupling halves are joined, the protruding nose (6) of the S4 half contacts the sleeve (4) of the S1 half. Simultaneously, the head of the tubular valve (1) contacts the face of the poppet valve (7), thus preventing foreign matter from entering the system.

Tightening the union pulls the coupling halves together. This causes the nose of the S4 half to push the sleeve into the S1 half, uncovering

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the ports of the tubular valve. At the same time, the head of the tubular valve depresses the poppet valve.

When the coupling halves are fully connected, the sleeve and poppet valve have reached the positions shown in the lower left-hand view of figure 5-19. The nose of the S4 half has engaged the O-ring packing of the S1 half, providing a positive seal.

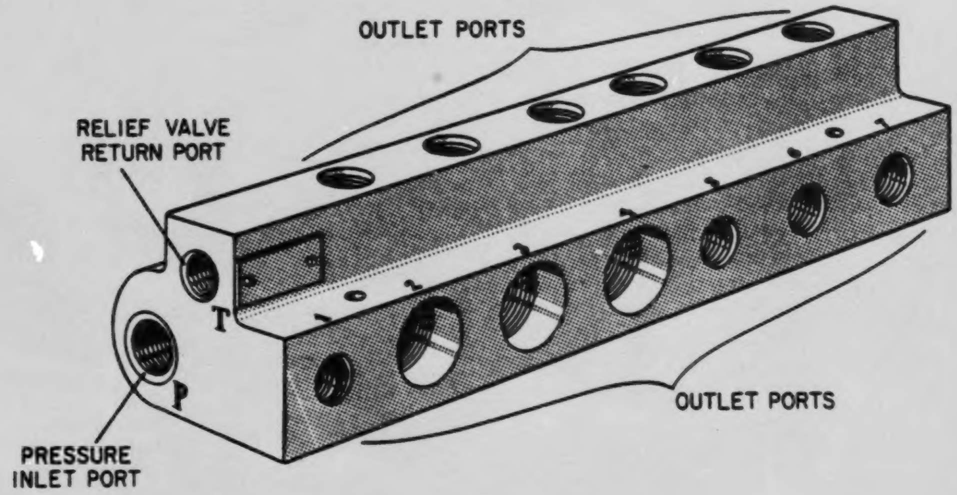
Dust caps are usually provided with quick-disconnect couplings to cover the ends of the coupling when it is disconnected.

MANIFOLDS

Some fluid power systems are equipped with manifolds in the pressure supply and/or return lines. A manifold is a fluid conductor which provides multiple connection ports. Manifolds serve to eliminate piping, to reduce joints which are often a source of leakage, and to conserve space. For example, manifolds may be used in systems that contain several subsystems. One common line connects the pump to the manifold. There are outlet ports in the manifold to provide connections to each subsystem. A similar manifold may be used in the return system. Lines from the control valves of the subsystem connect to the inlet ports of the manifold where the fluid combines into one outlet line to the reservoir. Some manifolds are equipped with the check valves, relief valves, filters, etc., required for the system. In some cases, the control valves are mounted on the manifold in such a manner that the ports of the valves are connected directly to the manifold.

Manifolds are usually one of three types—sandwich, cast, or drilled. The sandwich type is constructed of three or more flat plates. The center plate (or plates) is machined for passages, and the required inlet and outlet ports are drilled into the outer plates. The plates are then bonded together to provide a leakproof assembly. The cast type of manifold is designed with cast passages and drilled ports. The casting may be iron, steel, bronze, or aluminum, depending upon the type of system and fluid medium. In the drilled type manifold, all ports and passages are drilled in a block of metal.

A simple manifold is illustrated in figure 5-20. This manifold contains one pressure inlet port and several pressure outlet ports. Since any number of the outlet ports can be blocked off with threaded plugs, this type manifold can be adapted to systems containing various numbers of subsystems. A thermal relief valve may be incorporated in this manifold. In this case, the port labeled (T) is connected to the



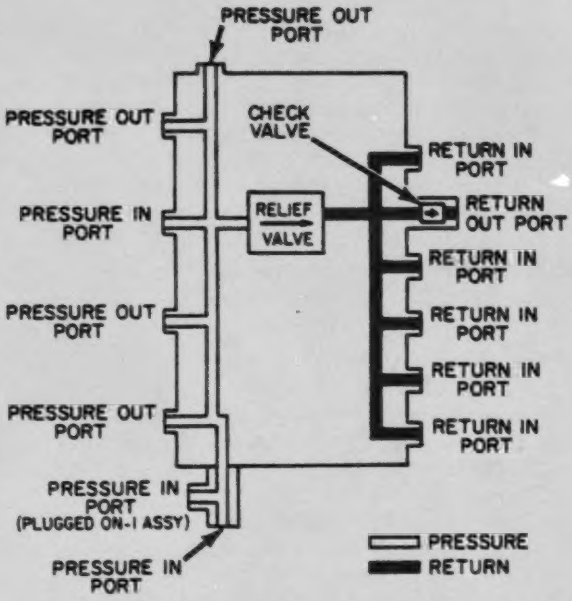
FP.67

Figure 5-20.—Fluid manifold.

707

return line to provide a passage for the relieved fluid to flow to the reservoir.

Figure 5-21 shows a flow diagram in a manifold which provides both pressure and return passages. One common line provides pressurized fluid to the manifold, which distributes the fluid to any one of five outlet ports. The return side of the manifold is similar in design. This manifold is provided with a relief valve, which is connected to the pressure and return passages. In the event of excessive pressure, the relief valve opens and allows the fluid to flow from the pressure side of the manifold to the return side.


PRESSURE OUT PORT
PRESSURE OUT PORT
CHECK VALVE
RETURN IN PORT
PRESSURE IN PORT
RELIEF VALVE
RETURN OUT PORT
RETURN IN PORT
PRESSURE OUT PORT
RETURN IN PORT
RETURN IN PORT
PRESSURE OUT PORT
RETURN IN PORT
PRESSURE IN PORT (PLUGGED ON-I ASSY)
PRESSURE IN PORT
PRESSURE
RETURN

FP.68

Figure 5-21.—Fluid manifold—flow diagram.

Although manifolds are used mostly in hydraulic systems, the demand for them in pneumatic systems is increasing.

PRECAUTIONARY MEASURES

The fabrication, installation, and maintenance of specific fluid lines and connectors are beyond the scope of this training manual. However, there are some general precautionary measures that apply to the maintenance of all fluid lines. Some of these are discussed in the following paragraphs.

It should be emphasized that regardless of the type of lines or connectors used to make up a fluid power system, make certain that they are the correct size and strength and perfectly clean on the inside. All lines must be absolutely clean and free from scale and other foreign matter. Iron or steel pipes, tubing, and fittings can be cleaned with a boiler tube wire brush or with commercial pipe cleaning apparatus. Rust and scale can be removed from short, straight pieces by sandblasting, provided there is no danger that sand particles will remain lodged in blind holes or pockets after the piece is flushed. In the case of long pieces or pieces bent to complex shapes, rust and scale can be removed by pickling (cleaning metal in a chemical bath). Parts must be degreased prior to to pickling. The manufacturer of the parts should provide complete pickling instructions.

Open ends of pipes, tubing, hose, and fittings should be capped or plugged when they are to be stored for any considerable period. Rags or waste must not be used for this purpose, because they deposit harmful lint which can cause severe damage to the fluid power system.

CHAPTER 6

SEALING DEVICES AND MATERIALS

As related in chapter 1, Pascal's theorem, from which evolved the fundamental law for the science of hydraulics, was proposed in the 17th century. One stipulation that was necessary to make the law effective for practical applications was a piston that would "fit" the opening in the vessel "exactly." This was not accomplished until over 100 years later. It was late in the 18th century when an Englishman, Joseph Brahmah, invented the cup packing which led to the development of the hydraulic press.

The packing was probably the most important invention in the development of hydraulics as a leading method of transmitting power. Of course, the invention and development of machines to cut and shape closely fitted parts were also very important in the development of hydraulics. However, some type of packing is usually required to make the piston, and many other parts of hydraulic components, to "fit exactly." This also applies to the components of pneumatic systems.

Through years of research and experiments, many different materials and designs have been used in the development of suitable packing devices. The materials must be durable and provide effective sealing. In addition, the materials must be compatible with the fluid used in the system. Several different designs are necessary to satisy the various requirements of fluid power systems.

These packing materials are commonly referred to as seals or sealing devices. In turn, the seals used in fluid power systems and components are divided into two general classes—static seals and dynamic seals. The static seal, usually referred to as a gasket, is used to provide a seal between two parts where no relative motion is involved. For example, gaskets are used in the assembly of cover plates on reservoirs and end plates or other nonmoving parts of certain types of pumps, motors, valves, etc.

The dynamic seal is commonly referred to as a packing. The packing is used to provide a seal between two parts which move in relation to each other; for example, a piston which moves back and forth within a cylinder. These two classifications of seals—gaskets and packings—will apply in most cases; however, deviations may be found in some technical publications. It should be noted that certain types of seals (for example, the O-ring which is discussed later) may be used either as a gasket or a packing.

Many of the seals in fluid power systems prevent external leakage. These seals provide a twofold purpose—to seal the fluid in the system and to keep foreign matter out of the system. Other seals simply prevent internal leakage within a system. These applications are illustrated in figure 6-1. Gaskets are installed between the cylinder wall and the end caps (points (A) and (B)) to prevent external leakage. A packing is installed between the piston rod and one end cap (point (D)) which also prevents external leakage. A packing is also installed on the piston (point (C)) to prevent internal leakage.

NOTE: Although leakage of any kind results in a loss of efficiency, some leakage, especially internal leakage, is desired in hydraulic systems to provide lubrication of moving parts. This also applies to some pneumatic systems in which drops of oil are introduced into the flow of air in the system. As a result, a slight amount of internal leakage within the system provides lubrication of moving parts.

The first part of this chapter deals primarily with the characteristics of the different types of materials used in the construction of seals. The next section is devoted to the different shapes and designs of seals and their application as gaskets and/or packings in fluid power systems. Most emphasis is on the O-ring, since it is the most common seal used in fluid power systems. Also included in this chapter are sections

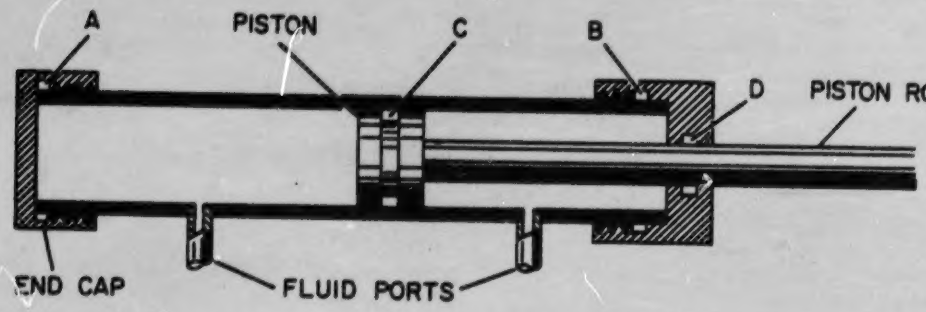


Figure 6-1.—Application of seals

FP.69

concerning the functions of wipers and backup washers in fluid power systems and on the selection, storage, and handling of sealing devices.

MATERIALS

As mentioned previously, several different types of material are used in the construction of seals. In the early years of fluid power, seals were made of such materials as rope, sawdust, rags, etc. These materials were jammed into a stuffing box by means of a packing gland. The use of such materials led to extrusion of the material through clearance spaces, rapid wear and continual leakage in varying amounts. Therefore, these seals demanded almost constant attention.

Natural rubber has many of the characteristics required in an effective seal. However, as discussed in chapter 3, natural rubber is not compatible with petroleum base fluids. Since this type fluid is commonly used in hydraulic systems and petroleum base oils are used as lubricants in pneumatic systems, natural rubber seals have limited use in fluid power systems. They are sometimes used in automotive brake systems, which utilize vegetable base fluids.

Today, seals are made of materials which have been carefully chosen or developed for specific applications. These materials include synthetic rubber, cork, leather, and metal. Asbestos seals are sometimes used where heat is a problem. Some of the most common materials used in the construction of seals for fluid power systems are discussed in the following paragraphs.

SYNTHETIC RUBBER

Although experiments were conducted in the search for a synthetic rubber in the 1800's and early 1900's, it was late in the 1930's before suitable synthetic compositions were developed. Among other desirable characteristics, some of these compositions were resistant to petroleum base fluids and, therefore, became the leading materials for fluid power seals. Since then, great advancements have been made in this field. New synthetics have been developed and the earlier synthetics have been improved.

The basic substance used in the composition of many synthetic rubbers is petroleum or alcohol. Different chemicals are added to the basic substance to obtain different synthetics. The names of these different synthetics are usually derived from their chemical composition. Butyl, buna N, neoprene, polyacrylate, thiokol, ethylene propylene, and fluorosilicone are some of the synthetic compositions available. Seals made of such synthetics as ethylene propylene and fluorosilicone are required in systems containing the newer synthetic fluids. Seals made of butyl and buna N are used in some fluid power systems. However, neoprene, which was one of the first synthetic compositions, is the most widely used material in making seals for fluid power systems.

Many factors contribute to make synthetic rubber ideal for fluid power seals. This material is virtually impermeable (prevents passage of fluid) in a compressed state and, therefore, requires less sealing load than many other types of seals. Synthetic rubber is easily formed and is available in sheet form and in molded shapes for different applications. Several types of synthetic rubber seals are capable of functioning in temperature ranges as wide as -65° to 300° F. Some of the newer synthetics can withstand even greater temperature ranges.

There are two general classes of synthetic rubber seals. One class is made entirely of a certain synthetic rubber. The term homogeneous, which means having uniform structure or composition throughout, is frequently used to describe this class of seal. The other class of seal is made by impregnating woven cotton duck or fine-weave asbestos with synthetic rubber. This class is sometimes referred to as fabricated seals. (Natural rubber impregnated seals are available for some applications.)

CORK

Cork has several of the required properties which make it ideally suited as a sealing material in certain applications. The compressibility of cork composition seals make them well suited for confined applications where no relief for side flow can be provided. In other words, cork can be compressed enough to provide an effective seal with only a limited spread of the material. Much of the compression is absorbed by the material itself.

Cork can be cut to any desired thickness and shape to fit any surface and still provide an excellent seal. It can withstand sustained temperatures up to approximately 270° F.

One of the undersirable characteristics of cork is its tendency to crumble. Therefore, if cork seals were used as packings or in areas where there is a high fluid pressure and/or high flow velocity, small particles would be cast off into the system. For this reason, cork seals have limited use in fluid power systems. Cork gaskets are sometimes used under the inspection plates on hydraulic reservoirs.

CORK AND RUBBER

Cork and rubber seals are made by combining synthetic rubber and cork. This combination allows a sealing material having the properties of both of the two materials. This means that seals can be made with the compressibility of cork, but with a resistance to fluid comparable to the synthetic rubber on which they are based. Cork and rubber composition is sometimes used as gaskets for applications similar to those described for cork gaskets.

METAL

One of the most common metal seals used in Navy equipment is copper. Flat copper rings are sometimes used as gaskets under adjusting screws to provide a fluid seal. Molded copper rings are sometimes used as a packing with speed gears operating under high pressures. Either type is easily bent and requires careful handling. In addition, copper becomes hard when used over long periods or is subjected to compression. Whenever a unit or component is disassembled, the copper sealing rings should be replaced. However, if new rings are not available and the part must be repaired, the old ring should be softened by annealing. (Annealing is the process of heating a metal, then cooling, so as to make the metal more pliable and less brittle.)

Metallic piston rings are used as a packing in some fluid power actuating cylinders. These rings are similar in design to the piston rings in automobile engines. In some instances, this automotive type ring is made of Teflon.

TYPES OF SEALS

Fluid power seals are usually typed in accordance with their shape or design. These types include O-rings, Quad-rings, V-rings, U-rings, cup seals, and flange seals. Figure 6-2 illustrates some of these seals. A section is cut out of each seal to show the cross-sectional shape. A few of the more common seals used in fluid power systems are discussed in the following paragraphs.

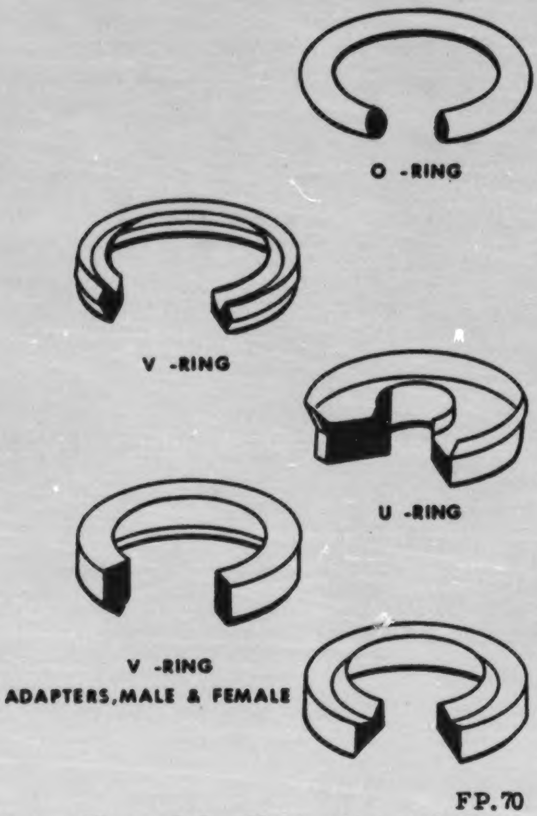


Figure 6-2.—Fluid power seals.

O-RINGS

An O-ring, as shown in figure 6-2, is circular in shape, and its cross section is small in relation to its diameter. The cross section is truly round and has been molded and trimmed to extremely close tolerances. The ellipitcal seal is also included in this discussion. This seal is similar to the O-ring except for its cross-sectional shape. As its name implies, its cross section is elliptical in shape.

Some O-rings are made of natural rubber; however, most are made of one of the synthetic compositions. The O-ring is usually fitted into a rectangular groove machined into the mechanism to be sealed. As stated previously, O-rings may be used as gaskets or packings, and are used to prevent external or internal leakage. The O-ring forms the seal by distortion of its resilient, elastic compound, thus filling the leakage path.

Figure 6-3 shows the proper installation of an O-ring seal. The clearance for the seal is less than its free outer diameter, and the O-ring is squeezed diametrically out-of-round even before the application of pressure. (See view (A), fig. 6-3.)

When pressure is applied to the O-ring, the seal moves away from the pressure into the path of the possible leakage (fig. 6-3 (B)). The O-ring is designed so that the seal flows up to the passage, thus completely sealing it against leakage. The greater the pressure applied, the tighter the seal becomes. When the pressure is decreased, the resiliency and elasticity of the seal results in the O-ring returning to its natural shape.

Identification and Inspections

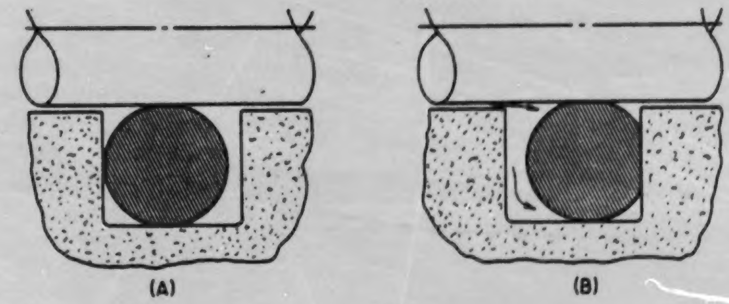
Individuals working with fluid power systems must be able to positively identify, inspect, and install the correct size and type O-ring for every application in order to insure the best possible service.

The task of procuring and positively identifying the correct seal can be difficult since part numbers cannot be put directly on the seals. In addition, there is a continual introduction of new types of seals and obsolescence of others.

Most O-rings are identified with a color code to denote the specific use for which they are intended. Colored dots, dashes, and stripes, or combinations of dots and dashes on the surface of the O-ring indicate the medium (air, gas, or other type of fluid medium) in which the O-ring is usable. Identification marks are read clockwise around the ring.

The first mark on the O-ring indicates the fluid medium. A blue dot or blue stripe indicates a seal that is used with air and/or petroleum base hydraulic fluid. The next mark following the first identification mark denotes the manufacturer; however, in some instances manufacturer's marks are not required.

Color coding of O-rings is not always a complete and reliable means of identification. There are several limitations to the color



FP.71

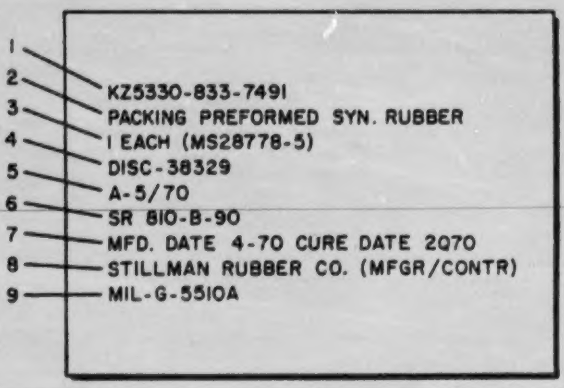
Figure 6-3.—Properly installed O-ring.

coding. Some coding is not permanent, while it may be omitted on some O-rings due to manufacturing difficulties or interference with operation. Furthermore, the color system provides no means to establish the size, age, and other important data. For these reasons, O-rings are made available in individually sealed envelopes labeled with all the necessary pertinent data. It is recommended that they be processed and stocked in these envelopes. An example of the information printed on the O-ring envelope is illustrated in figure 6-4.

When selecting an O-ring for installation, information on the package should be carefully observed. If an O-ring cannot be positively identified, it should be discarded. The part number on the sealed package provides the most reliable and complete identification.

Although an O-ring may appear perfect at first glance, slight surface flaws may exist. These are often capable of preventing satisfactory O-ring performance under the variable operating pressures of fluid power systems. Therefore, O-rings should be rejected for any flaws that will affect their performance.

By rolling the ring on an inspection cone or dowel, the inner diameter surface can be checked for small cracks, particles of foreign matter, and other irregularities that will cause leakage or shorten the life of the O-ring. The slight stretching of the ring when it is rolled inside out will help to reveal some defects not otherwise visible. A further check of each O-ring should be made by stretching it between the fingers, but care must be taken not to exceed the elastic limits of the rubber.



1 KZ5330-833-7491
2 PACKING PREFORMED SYN. RUBBER
3 I EACH (MS28778-5)
4 DISC-38329
5 A-5/70
6 SR 810-B-90
7 MFD. DATE 4-70 CURE DATE 2Q70
8 STILLMAN RUBBER CO. (MFGR/CONTR)
9 MIL-G-5510A

FP.72

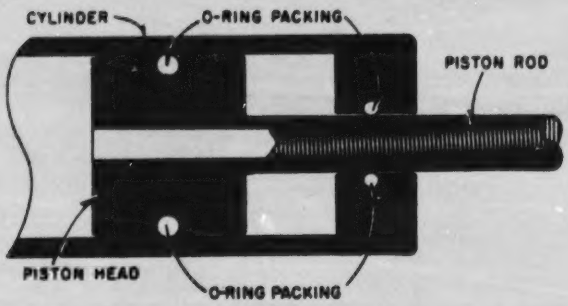
1. Stock number.
2. Nomenclature.
3. Part number.
4. Contract number.
5. Preservation.
6. Rubber composition number.
7. Date of manufacture and cure date.
8. Manufacturer.
9. Military specification number.

Figure 6-4.—O-ring package identification.

Following these inspection practices will prove to be a maintenance economy. It is far more desirable to take special care identifying and inspecting O-rings prior to installation than to repeatedly overhaul components because of faulty seals.

O-Ring Replacement

Figure 6-5 shows a typical O-ring installation. When such an installation shows signs of internal or external leakage, the component must be disassembled and the seals replaced. Sometimes components must be resealed because of the age limitations of the seals. Age limitation is discussed later in this chapter. Some of the precautions that must be observed when replacing O-ring seals are discussed in the following paragraphs.



FP.73

Figure 6-5.—Typical O-ring installation.

After disassembly of the component in accordance with the applicable technical instructions, the first step in replacing an O-ring is to identify it both as to size and material. The part number of the seal required for each application should be listed in the applicable parts manual for the specific equipment. This number should correspond with the part number on the package of the replacement seal. (See item 3, fig. 6-4.) This number will usually be an MS (Military Standard) number. The complete number must be checked since the dash number indicates the size of the O-ring. For example, in the number MS28778-5, the -5 indicates the size of the O-ring.

After determining that the replacement seal is made of the correct material and is of the proper size, the seal should be inspected for cuts, nicks, or flaws following the procedures discussed previously. If any defects appear, the seal should be discarded.

Prior to installation, the O-ring grooves, and all surfaces over which the O-ring must slide should be lubricated. In hydraulic systems, this lubricant should be fluid of the type that is used in the system. In pneumatic systems, these surfaces should be coated with a lubricant which has a high melting point. Barium and lithium soap grease is recommended for use in low-pressure systems, while a silicone lubricant is recommended for use in pneumatic systems that have pressures of 1,000 psi or more. Since this lubricant must be compatible with the seal material, the correct lubricant is sometimes listed in the technical publications for the specific system. Therefore, the applicable technical instructions should be consulted before lubricant is applied to seals and sealing surfaces of pneumatic systems.

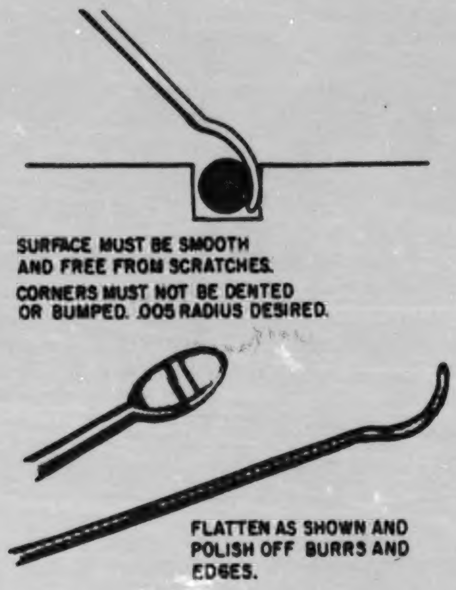
Felt washers are sometimes installed on both sides of the O-ring. These felt washers will retain the lubricant for a long period of time. Installations and fittings can be provided so that the washers can be lubricated periodically.

O-ring installation often requires spanning or inserting the O-ring through sharp threaded areas, ridges, slots, and edges. Such areas should be covered with an O-ring entering sleeve (soft, thin-wall metallic sleeve). If the recommended O-ring entering sleeve is not available, paper sleeves and covers may be fabricated by using the seal package (glossy side out) or lint-free bond paper. Adhesive tapes should not be used to cover these danger areas. Gummy substances left by the adhesives are extremely detrimental to fluid power systems.

After the O-ring is placed in the cavity provided, it should be gently rolled with the fingers to remove any twist that might have occurred during installation.

When removing or installing O-rings, the use of pointed or sharp-edged tools which might cause scratching or marring of component surfaces or cause damage to the O-ring should be avoided. Special tools may be fabricated for this purpose. A few examples of tools used in the removal and installation of O-rings are illustrated in figure 6-6. These tools should be fabricated from soft metal such as brass or aluminum; however, tools made from phenolic rod, wood, or plastic may also be used. In fact, plastic tools of this type are available in kits through the supply system.

The O-ring seal, when used alone, is limited to systems having maximum operating pressures


SURFACE MUST BE SMOOTH AND FREE FROM SCRATCHES.
CORNERS MUST NOT BE DENTED OR BUMPED. .005 RADIUS DESIRED.
FLATTEN AS SHOWN AND POLISH OFF BURRS AND EDGES.

FP.74

Figure 6-6.—O-ring removal and installation tools.

of 1,500 psi or less. This is particularly true when the O-ring is used as a packing. In systems with operating pressures above 1,500 psi; backup washers are installed in conjunction with the seal. Backup washers are discussed later in this chapter.

QUAD-RINGS

The Quad-ring is very similar to the O-ring discussed previously; the major difference being that the Quad-ring has a modified square type of cross section, as shown in figure 6-7. Like O-rings, Quad-rings are molded and trimmed to extremely close tolerances in cross-sectional area, inside diameter, and outside diameter.

The Quad-ring is relatively new and is presently used as a packing for reciprocating or rotary motion and can also be used as a static seal. The composition and the design of Quad-rings are such that they could be used in most applications in place of O-rings. The relatively square cross section of the Quad-ring helps to eliminate the spiral twist that is sometimes encountered with the O-ring.

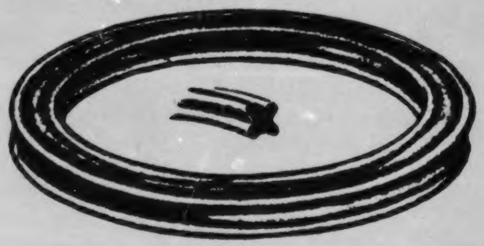


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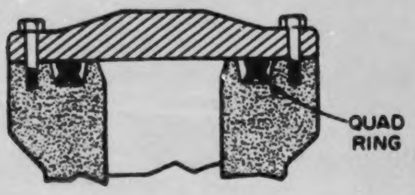
Figure 6-7.—Quad-ring.

The elimination of the spiral twist will in many instances extend the life of the seal.

Quad-rings are ideally suited for both low pressures and extremely high pressures. An example of a Quad-ring used as a cover gasket is illustrated in figure 6-8.



FP.76

Figure 6-8.—Quad-ring used as cover gasket.

V-RINGS

Several years ago, the V-ring was the predominant seal used in fluid power systems. In recent years it has been replaced by the O-ring in most applications. However, V-rings are still used in some applications.

Unlike the O-ring the V-ring seal will provide a seal in only one direction. Therefore, if a piston is to move in two directions under pressure, two sets of V-rings must be used. V-rings are always installed with the open end of the V facing the pressure. Male and female adapters are used in conjunction with V-rings for reinforcement. A V-ring and male and female adapters are illustrated in figure 6-2. A V-ring installation is illustrated in figure 6-9.

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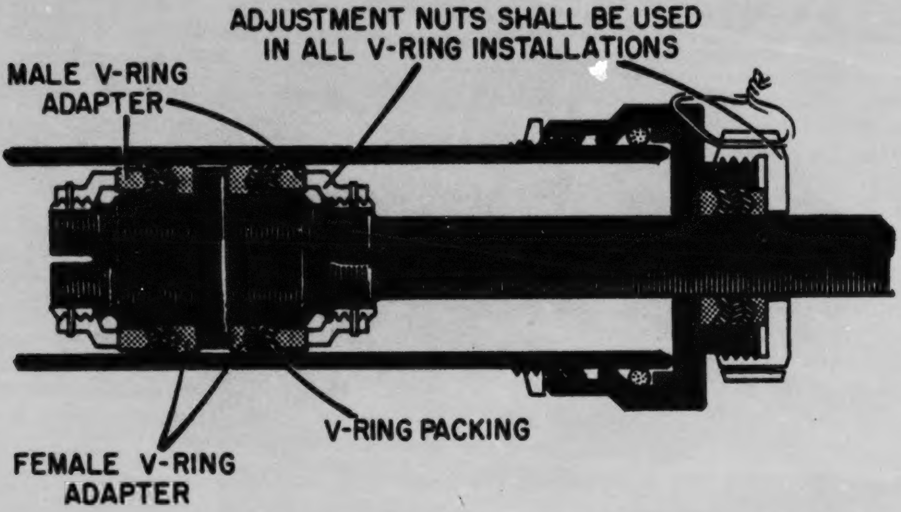


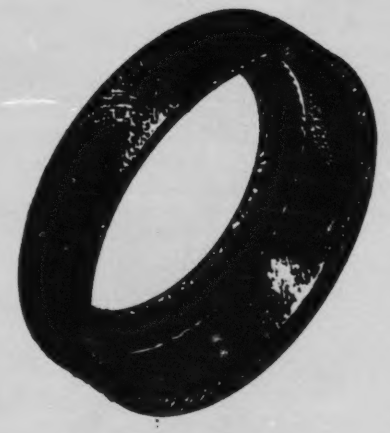
FP.77

Figure 6-9.—V-ring installation.

Installation of V-rings is slightly different from that of O-ring seals. The rings and adapters are placed in their respective grooves, one at a time. After the rings and adapters are seated properly, the adjusting nut is tightened. (See fig. 6-9.) The adjusting nut should be tightened enough to hold the seals securely. If possible, the unit should be operated by hand to check the adjustment.

CUP SEAL

The cup seal is sometimes used as a piston seal in fluid power systems. The cup seal is generally made of synthetic rubber or leather. Some cup seals are made of fabricated synthetic material, described earlier in this chapter. As the name implies, the cup seal is made in the shape of a cup. A typical cup seal is illustrated in figure 6-10.

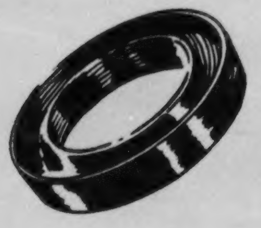


FP.78

Figure 6-10.—Typical cup seal.

U-RINGS

U-rings are used to prevent leakage in one direction only. Typical uses of the U-ring are in automotive hydraulic brake assemblies and brake master cylinders. U-rings are never used where high pressures will be encountered. As with O-rings, when U-rings are used in pneumatic systems, provisions must be made to lubricate the seal. A typical U-ring seal is shown in figure 6-11.

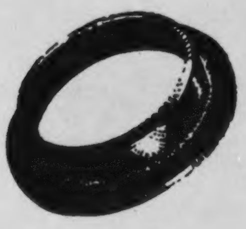


FP.79

Figure 6-11.—Typical U-ring seal.

FLANGE SEALS

Flange seals are sometimes used as packings in some fluid power systems. This type packing is recommended for use only in low-pressure applications. Flange packings are the least desirable of the previously described types of seals. They are normally used only where there is not sufficient space for either a V-ring packing or a U-ring packing. Flange packings are sometimes referred to as "hat packings." A typical flange packing is illustrated in figure 6-12.



FP.80

Figure 6-12.—Flange packing.

WIPERS AND BACKUP WASHERS

Although wipers and backup washers are not classified as seals, they definitely serve a vital role in the effectiveness and the life of seals in certain applications. Their functions and applications are discussed in the following paragraphs.

WIPERS

Wipers, which are sometimes referred to as scrapers, are used to clean and lubricate the exposed portion of piston rods. This prevents foreign matter from entering the system and scoring internal surfaces and damaging seals. Wipers may be of the metallic (usually copper base alloys) or felt types. In some applications, they are used together, the felt wiper being installed behind the metallic wiper. In hydraulic systems, the felt wiper is normally lubricated with system hydraulic fluid from a drilled passage or from an external fitting. In pneumatic systems, the felt wiper is lubricated with the approved lubricant from an external fitting.

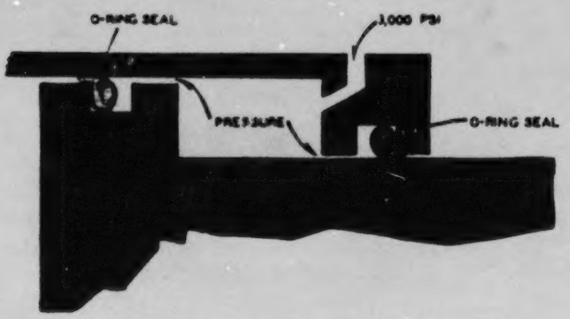
Wipers are manufactured for a specific component and must be ordered for that application. Wipers are normally inspected and changed, if necessary, while component repair is in process.

Metallic wipers are formed in split rings for ease in installation and are manufactured slightly undersize to insure a tight fit. One side of the metallic wiper has a lip which should face outward upon installation. Metallic wipers should be inspected for foreign matter and condition and then installed over the piston shaft in the proper order, as directed by the applicable technical instructions.

The felt wiper may be a continuous felt ring or a length of felt with sufficient material to overlap its ends. The felt wiper should be soft, clean, and well saturated with the appropriate lubricant during installations.

BACKUP WASHERS

One of the major problems concerning seals is the problem of extrusion. Extrusion may be defined as distortion, under pressure, of portions of the seal into the clearances between mating metal parts. The extrusion of O-rings is illustrated in figure 6-13. When pressure is applied, the seals will flow into the respective clearances. When the pressure is released, the O-rings return to their original shape. However, the extrusion groove will appear as a cut beneath the surface of the O-ring. Eventually, the cuts will become more severe, and sections will be cut out of the O-rings. This, of course, will lead to the failure of the O-ring.

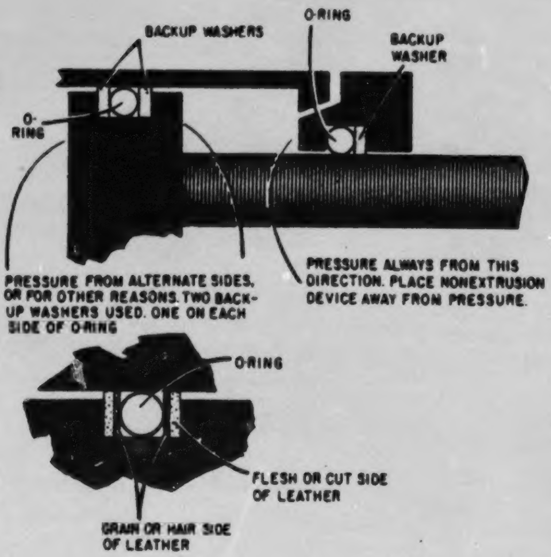

O-RING SEAL
1,000 PSI
PRESSURE
PRESSURE
O-RING SEAL

FP.81
Figure 6-13.—Extrusion of O-rings.

To eliminate extrusion, the manufacturer must use harder seals, reduce clearances, or use backup washers. Backup washers are commonly used for this purpose. A backup washer is a device normally used behind a seal to allow a higher pressure to be applied to the seal. A backup washer used behind an O-ring, for example, will extend the allowable seal pressure from 1,500 psi to pressures in excess of 3,000 psi. If the O-ring is subject to pressures from alternating sides, backup washers are required on both sides of the O-ring. An installation of O-rings with backup washers is illustrated in figure 6-14.

When a part or component is disassembled and the packing is being replaced, the backup washers should also be thoroughly inspected. Inspection of backup washers should include a check that surfaces are free from irregularities, that edges are clean-cut, and that scarf cuts are parallel. Tools similar to those used in the removal and installation of O-rings should be used for the removal and installation of backup washers.

The size of a backup washer is indicated by a dash number. The dash number of the backup washer should be the same as the dash number of the packing with which it is to be used. Most backup washers are packaged in envelopes similar to those described for O-rings. Information concerning the backup washers is printed on the envelope. It is recommended that the backup washer be retained in the envelope until required.


BACKUP WASHERS
O-RING
BACKUP WASHER
O-RING
PRESSURE FROM ALTERNATE SIDES, OR FOR OTHER REASONS. TWO BACKUP WASHERS USED. ONE ON EACH SIDE OF O-RING
PRESSURE ALWAYS FROM THIS DIRECTION. PLACE NONEXTRUSION DEVICE AWAY FROM PRESSURE.
O-RING
FLESH OR CUT SIDE OF LEATHER
GRAIN OR HAIR SIDE OF LEATHER

FP.82
Figure 6-14.—O-ring with backup washers.

Presently, backup washers are made of thin split metal, bakelite, chrome tanned leather, or Teflon. Leather and Teflon are the most widely used. These two types of backup washers are described in the following paragraphs.

Leather

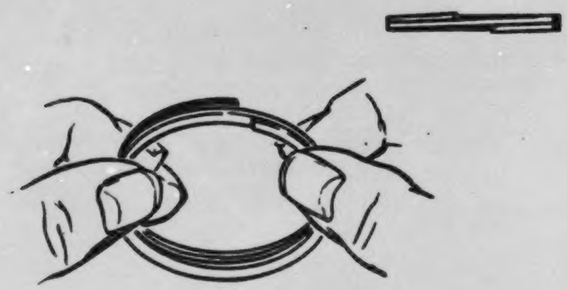
The chrome tanned leather backup washer is made of leather with hair on the outer side of the leather. The outer side of the leather is called the grain side, while the cut or inside of the leather is called the flesh side. The backup washer is always installed in the gland (groove). The flesh side of the backup washer is always next to the gland. This positions the grain side to the seal. (In this case, the seal is an O-ring.) If the pressure is exerted on the seal in one direction only, the washer is placed away from the pressure. If pressure is to be applied alternately from both directions, one backup washer must be placed on each side of the O-ring.

NOTE: Leather backup washers should never be cut, as results have shown that when pressure is applied, this will be the section most likely to fail.

Teflon

Backup washers made of Teflon do not deteriorate with age, are unaffected by any system fluid or vapor, and tolerate temperature extremes in excess of those encountered in high-pressure fluid power systems. Teflon backup rings may be stocked in individual sealed envelopes similar to those in which O-rings are packed, or several may be installed on a cardboard mandrel.

Teflon backup washers are usually of the spiral design, as illustrated in figure 6-15. When dual backup washers are installed, the split scarfed ends must be staggered.



FP.83

Figure 6-15.—Teflon spiral backup washer.

SELECTION, STORAGE, AND HANDLING

The selection, storage, and handling of all types of seals are very important to the effectiveness and to the life of the seal. The correct seal must be selected for the job and must be protected from outside elements during the time it is in storage. Some of the precautionary measures that must be considered in the selection, storage, and handling of fluid power seals are discussed in the following paragraphs.

SELECTION

The selection of the correct packings and gaskets is an important factor in maintaining an efficient fluid power system. Manufacturers specify the type of seals to be used in their equipment, and their instructions should be followed when replacing these items. If the proper seal is not available, careful consideration should be given to the selection of a suitable substitute.

As discussed in the section on O-rings, applicable technical instructions should be consulted to select the correct replacement seal in a specific system. To simplify the selection of many types of packings and gaskets commonly used in naval service, the Naval Ships Systems Command has prepared a packing and gasket chart (Mechanical Standard Drawing B-153) showing the symbol numbers and the recommended applications of most types of packing and gasket materials. The symbol number used to identify each type of packing and gasket consists of a four-digit number. The first digit indicates the class of seal; the numeral 1 indicates the seal is a packing and the numeral 2 indicates a gasket. The second digit indicates the principal material from which the seal is composed. The third and fourth digits indicate the different styles or forms of the seal.

In addition to the Naval Ships Systems Command chart, most ships have a packing and gasket chart made up specifically for each ship. The shipboard chart shows the symbol numbers and the sizes of packings and gaskets required in the ship's piping system and equipment.

STORAGE AND HANDLING

It has been found through experience that seal materials, especially natural and synthetic rubbers, will deteriorate with age. For this reason, the Navy has established an age control program for these materials. This program is known as shelf life. Knowing and understanding shelf life will save many hours of unnecessary toil experienced in repacking a unit and having it still leak because the packing was defective due to age.

Prior to installation of natural and synthetic rubber seals, a check must be made to determine if these parts are acceptable for use. All natural and synthetic rubber packing containers are marked to facilitate an age control program. (See item 7, fig. 6-4.) This information is available for all seals used regardless of whether the seal is stocked on shipboard, at stock distribution points, or furnished as an integral part of the component. Positive identification indicating the source, "cure date," and "expiration date" must be made of seals.

The age control of all seals is based upon the cure date stamped on the manufacturer's package. This cure date is denoted in quarters. For example, the cure date 2Q70, illustrated in figure 6-4, indicates that the seal was manufactured during the second quarter of 1970. Seals manufactured during any given quarter are not considered one quarter old until the end of the succeeding quarter. Most seal age limitations are determined by this cure date, anticipated service life, and replacement schedule.

The age of the seal is computed from the cure date. The term cure date is used in conjunction with replacement kits which contain seals, parts, and hardware for shop repair of various components. These cure dates also provide bases for seal replacement schedules, which are determined by the service life of the seal. The service life (estimated time of trouble-free service) of seals also depends upon such conditions as use, exposure to certain elements, both natural and imposed, and subjection to physical stress. Operational conditions imposed on seals in one component may necessitate seal replacement more frequently than replacement of identical seals in other components. Therefore, it is necessary to adhere to the recommended replacement schedule for each individual component. The age of seals in a spare part is determined from the assembly date recorded on the service or identification plate and/or the exterior of the container. All O-rings over 24 months old should be replaced or, if nearing their age limit (24 months), should not be used for replacement.

Proper storage practices must be observed to provent deformation and deterioration of seals. Most synthetic rubbers are not damaged by storage under ideal conditions. However, most synthetic rubbers will deteriorate when exposed to heat, light, oil, grease, fuels, solvents, thinners, moisture, strong drafts, or ozone (form of oxygen formed from an electrical discharge). Damage by exposure is magnified when rubber is under tension, compression, or stress. There are several conditions to be avoided which include the following:

1. Deformation as a result of improper stacking of parts and storage containers.
2. Creasing caused by force applied to corners and edges, and by squeezing between boxes and storage containers.
3. Compression and flattening, as a result of storage under heavy parts.
4. Punctures caused by staples used to attach identification.
5. Deformation and contamination due to hanging the seals from nails or pegs. Seals should be kept in their original envelopes, which provide preservation, protection, identification, and cure date.
6. Contamination by piercing the sealed envelope to store O-rings on rods, nails, or wire hanging devices.
7. Contamination by fluids leaking from parts stored above and adjacent to the seal surfaces.
8. Contamination caused by adhesive tapes applied to seal surfaces. A torn seal package should be secured with a pressure-sensitive moistureproof tape, but the tape must not contact the seal surfaces.
9. Retention of overage parts as a result of improper storage arrangement or illegible identification. Seals should be arranged so the older seals are used first.

CHAPTER 7

RESERVOIRS, STRAINERS, FILTERS, AND ACCUMULATORS

Fluid power systems must have a sufficient supply of uncontaminated fluid for the efficient operation of the system. Although the same fluid is recirculated in hydraulic systems, a container must be provided for a supply of fluid in excess of that contained in the lines and components. Since the fluid is expended during the operation of pneumatic systems, containers are also required to supply gas to these systems. As stated in chapter 3 and emphasized throughout this manual, fluid must be kept free of all foreign matter for efficient operation of the system. Various types of strainers and filters are incorporated in the system to provide this function.

The first part of this chapter covers the containers—hydraulic reservoirs and pneumatic receivers—used in fluid power systems. The next section of the chapter describes the different types of strainers and filters used in the filtration of fluids. The last part of the chapter is devoted to accumulators, another fluid supply source commonly used in hydraulic systems.

FLUID SUPPLY

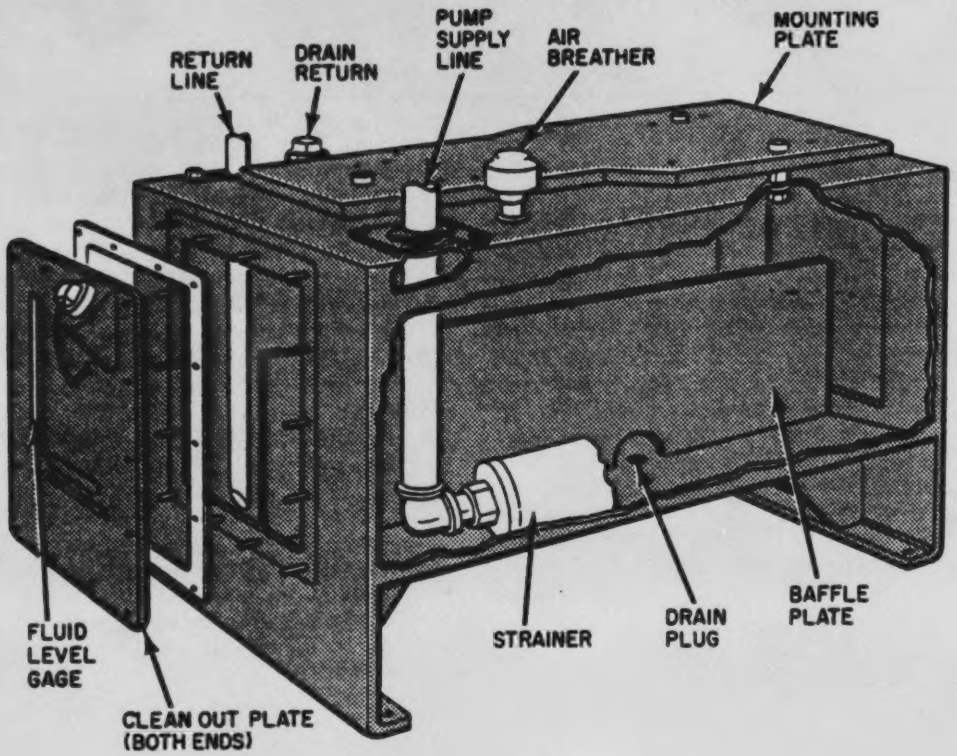
As previously stated, an adequate supply of the recommended fluid is a very important requirement for the efficient operation of a fluid power system. The reservoir, which provides a storage space for fluid in hydraulic systems, differs to a great extent from the receivers used for this purpose in pneumatic systems. For this reason, the two components are covered separately in the following sections.

HYDRAULIC RESERVOIRS

The reservoir is a basic component of any hydraulic system. In most systems the reservoir is a separate component of the system, while in other systems, for example the automatic transmission of an automobile, the reservoir also serves as the housing for the complete system. Although its primary function is to provide a storage space for the hydraulic fluid required by the system, a well constructed reservoir provides several additional functions. Among these functions are dissipation of heat, trapping of foreign matter, and the separation of air from the system.

Reservoirs dissipate heat by radiation from the external walls. In addition, some reservoirs are equipped with internal and/or external radiating devices such as cooling fins or coils. The trapping of foreign matter usually requires the use of strainers and/or filters, which are discussed later in this chapter. The separation of air from the system is accomplished by the design of the reservoir, which includes the incorporation of baffles to slow the fluid as it returns to the reservoir. The air bubbles have a greater chance of escaping to the surface of a liquid if the liquid moves at a slow velocity. Most reservoirs are equipped with a means whereby the air is vented to the atmosphere.

Many factors are considered when selecting the size and configuration of a hydraulic reservoir for a particular system. The reservoir must be large enough to store more than the anticipated volume of fluid that the system will require. The recommended reservoir volume is usually based on the gallon-per-minute flow demanded by the system. A reservoir capacity equal to two or three times the maximum rate of flow required by the system is usually sufficient. A higher ratio is desirable for fixed installation, and a somewhat lower ratio may be required for mobile equipment. Adequate space must be allowed to accommodate thermal expansion of the hydraulic fluid and changes in fluid level due to system operation.



FP.84

Figure 7-1.—Nonpressurized reservoir (ground or ship installation).

Reservoirs are of two general types—nonpressurized and pressurized. Nonpressurized reservoirs are vented to the atmosphere. This prevents a partial vacuum from being formed as the fluid level in the reservoir is lowered. The vent also makes it possible for any air that has entered the system to find a means of escape.

Aircraft and missiles designed for high-altitude operation require pressurized reservoirs. Pressurizing assures a positive flow of fluid to the pump at altitudes where low atmospheric pressure is encountered.

Nonpressurized Reservoirs

Hydraulic systems designed to operate equipment at or near sea level are normally equipped with nonpressurized reservoirs. This includes the hydraulic systems of ground and ship installations and some aircraft that are limited to low-altitude operations.

A typical reservoir for use with ground and ship installations is illustrated in figure 7-1. This type reservoir is made of hot rolled steel plates and welded seams. The ends extend below the bottom of the reservoir and serve as the support. The bottom of the reservoir is convex and a drain plug is incorporated at the lowest point.

Large removable covers are installed on each end of the reservoir to provide easy access for cleaning. One of the covers contains a fluid level indicator and a filler opening with a cap that is secured to the plate with a chain. Since the fluid level must be checked frequently, the indicator is located in a position where it can be easily read. A strainer is installed in the filler neck to prevent foreign matter from entering the reservoir when fluid is added.

In this type reservoir a baffle plate extends lengthwise through the center of the tank and separates the pump supply port from the system return port. The baffle usually extends from the bottom of the tank to approximately two-thirds the height of the normal fluid level. Usually, there are several openings in the baffle near the bottom of the reservoir. Therefore, the purpose of the baffle is not to completely divide the reservoir into two separate compartments, but rather to reduce turbulence created by return flow and to prevent the continuous recirculation of the same fluid. It also allows foreign matter to settle to the bottom of the reservoir and air bubbles to escape through the surface of the fluid before the fluid is recirculated.

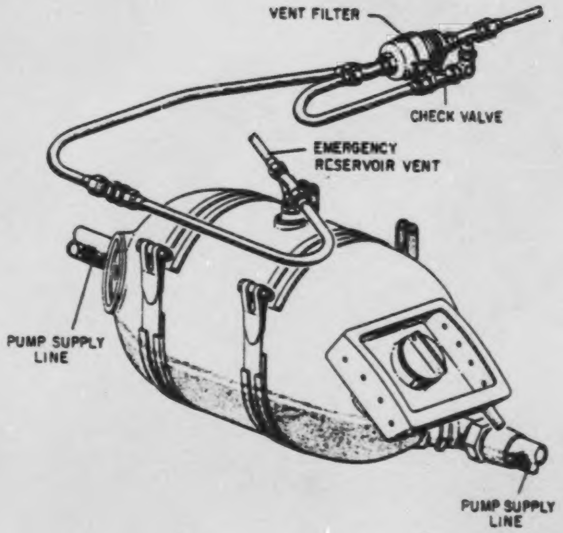
The vent (air breather) line contains a filter to purify the air that enters the reservoir. The vent assembly functions to allow the pressure in the reservoir to balance with atmospheric pressure and to filter the air which enters the reservoir when the fluid level is lowered due to system operation.

The pump supply line enters the reservoir at the top and extends to within a few inches of the reservoir bottom. This helps to prevent foreign matter which settles to the bottom of the reservoir from entering the system. Return lines must be well below the fluid surface level to prevent foaming. The end of the return line is usually cut at an angle of approximately 45 degrees and positioned so that the flow is directed toward the walls of the tank and away from the pump intake line. This provides for maximum heat dissipation.

The inside of the reservoir is painted with a sealer to minimize oxidation, which can be caused by condensation. The sealer must be of a composition that will not react chemically with the fluid specified for the system.

Because of the design of this type reservoir, a large portion of the harmful contaminants in the system will accummulate in the reservoir, especially at the bottom. Therefore, the reservoir should be drained periodically and then flushed with a solvent compatible with the fluid that is used in the system. After cleaning, the reservoir should be filled to the proper level with clean hydraulic fluid of the type that conforms to the specification designated for the system. The system must then be operated for a few minutes to allow the fluid in the system to circulate through the reservoir and displace any air that may have entered the system. It should be noted at this point that some hydraulic systems are connected to the reservoir by a single line. This line serves as both supply and return line to and from the system. Since this prevents complete recirculation of the fluid in the system, air bleed valves are provided at various points in the system. The automobile brake system is a good example of this type system. Bleed valves are incorporated in the system at each wheel. After the air has been displaced in either type system, the fluid level must be rechecked and more fluid added if necessary. It should be emphasized that the fluid must be maintained at the level indicated on the gage. Remember there is a space provided above the fluid level for thermal expansion. A lesser amount of fluid than that indicated may result in improper performance of the system.

As mentioned previously, some aircraft hydraulic systems are equipped with nonpressurized reservoirs. A typical example of this type reservoir is illustrated in figure 7-2.



FP.85

Figure 7-2.—Nonpressurized reservoir (aircraft system).

Because of weight limitations in aircraft construction, the reservoirs are made of welded aluminum. The filler neck incorporates a removable metal screen assembly, which serves as a strainer.

A sight gage window for visually checking the fluid level is located on one end of the reservoir. The rim of this window is marked with lines indicating the refill level.

In addition to a filter, the vent assembly on this type reservoir usually contains a bypass check valve. The check valve allows air to be expelled from the reservoir at a greater rate than normal when large volumes of fluid are returned to the reservoir, and also prevents unfiltered air from entering the reservoir.

There are two pump supply line outlets—one supplies the main power pump, while the other outlet supplies the emergency pump. The outlet which supplies the main power pump is located a considerable distance above the outlet which supplies the emergency pump. This provides a reserve supply of fluid in the reservoir for the emergency system in the event that external leakage occurs during normal operation. The reserve supply of fluid should be of sufficient volume to operate the subsystems necessary for a safe landing of the aircraft. This includes such operations as the extension of the landing gear, the lowering of the flaps, and the operation of the brakes. The emergency and main system return lines, not shown in figure 7-2, are connected to ports on the side of the reservoir.

Maintenance of this reservoir consists mainly of cleaning the filler neck strainer and replacement of the vent filter. The filler neck strainer should be cleaned with a cleaning fluid that is compatible with the fluid used in the system. When cleaning the strainer, inspect for broken mesh (sometimes the result of servicing with a funnel).

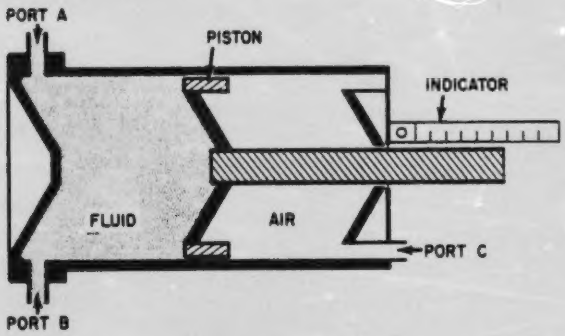
The vent filter element should be replaced in accordance with applicable technical publications. Additional information concerning strainers and filters are presented later in this chapter.

The cleanliness of the reservoir is maintained by periodic flushing similar to the procedures described in chapter 3.

Pressurized Reservoirs

As stated previously, many of the Navy's aircraft and missile hydraulic systems are equipped with pressurized reservoirs. This assures a positive flow of fluid to the pump at high altitudes where low atmospheric pressures are encountered. There are two common types of pressurized reservoirs—air-pressurized and hydraulic-fluid-pressurized.

AIR-PRESSURIZED.—One type of air-pressurized reservoir is illustrated in figure 7-3. The reservoir is cylindrical in shape and has a piston installed internally to separate the air and the fluid chambers. The end of the piston rod protrudes through the air chamber end of the reservoir and indicates the fluid quantity. The quantity indication may be seen by inspecting the distance the piston rod protrudes through the end of the cylinder.



FP.86

Figure 7-3.—Air-pressurized reservoir.

The air pressure is usually provided by bleed air taken from the compressor section of the engine. An air filler valve is usually incorporated in the air line to provide a means for pressurizing the reservoir during ground checks of the hydraulic system when the engine is not running. The air is filtered and the pressure is regulated to the required psi before it enters the reservoir through port (C). The required pressure is stipulated by the manufacturer.

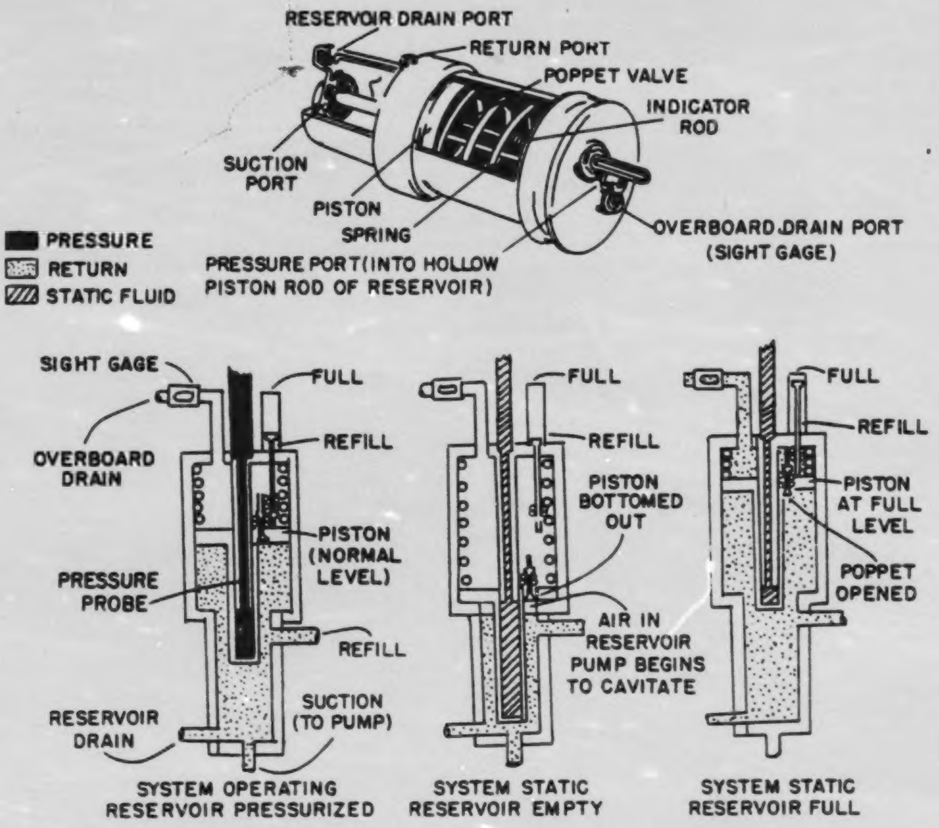
There are at least two ports—a supply port and a return port—in the fluid end of the reservoir. Some reservoirs contain additional ports to satisfy the requirements of certain systems. Provisions are incorporated, usually in the return line, to fill the reservoir from a single point. Filling is accomplished by forcing hydraulic fluid into the filler line. Applicable technical instructions must be adhered to when servicing this type reservoir.

In operation, the regulated air pressure enters the reservoir and acts on the piston, which in turn, transmits this force to the fluid. Thus, the pressurized fluid in the reservoir provides a positive flow of fluid through the supply line to the pump.

FLUID-PRESSURIZED.—Some hydraulic systems utilize system hydraulic pressure for pressurizing the reservoir. A reservoir of this type is shown in figure 7-4. This type reservoir is divided into two compartments by a floating piston. The floating piston is forced downward in the reservoir by a spring and by a pressure probe which fits into the piston.

The pressure probe is connected to the pump pressure line. Therefore, when the system is pressurized, hydraulic fluid under pressure enters the probe and aids the spring to force the piston downward, pressurizing the fluid in the lower compartment. This pressurizes the pump supply line to the same pressure. This pressure prevents pump starvation at all altitudes.

This type reservoir has five ports—pump supply, return, pump pressure, reservoir drain,


RESERVOIR DRAIN PORT
RETURN PORT
POPPET VALVE
INDICATOR ROD
SUCTION PORT
PISTON
SPRING
OVERBOARD DRAIN PORT (SIGHT GAGE)
PRESSURE PORT (INTO HOLLOW PISTON ROD OF RESERVOIR)
■ PRESSURE
▨ RETURN
▨ STATIC FLUID
SIGHT GAGE
FULL
REFILL
OVERBOARD DRAIN
PISTON (NORMAL LEVEL)
PRESSURE PROBE
REFILL
RESERVOIR DRAIN
SUCTION (TO PUMP)
SYSTEM OPERATING RESERVOIR PRESSURIZED
FULL
REFILL
PISTON BOTTOMED OUT
AIR IN RESERVOIR PUMP BEGINS TO CAVITATE
SYSTEM STATIC RESERVOIR EMPTY
FULL
REFILL
PISTON AT FULL LEVEL
POPPET OPENED
SYSTEM STATIC RESERVOIR FULL

FP.87

Figure 7-4.—Fluid-pressurized reservoir.

and overboard drain. Fluid is supplied to the pump through the pump supply port. Fluid returns to the reservoir from the system through the return port. Pressure from the system enters the pressure probe in the top of the reservoir through the pump pressure port. The reservoir drain port is for the purpose of draining the reservoir, when draining is necessary. The line leading from the overboard drain port is equipped with a sight gage which is used as an aid in servicing the reservoir.

When servicing the reservoir, a container should be placed under the line leading from the overboard drain port. Fluid is forced into the reservoir through a fill port in the return line. The liquid should be forced into the reservoir until air-free liquid flows through the sight gage. (Air-free liquid is liquid containing no air bubbles.)

An indicator rod that protrudes through the top of the reservoir housing is used in determining when the reservoir needs servicing. The word REFILL is stamped on the rod guide. When the reservoir is full, the rod is extended and the word REFILL is hidden; when the rod is retracted, the word REFILL is exposed and the reservoir needs servicing.

PNEUMATIC RECEIVERS

Like hydraulic systems, pneumatic systems require an adequate supply of fluid for the efficient operation of the system. In all cases, the supply of gas for pneumatic systems must be stored under pressure. The amount of pressure, and also the volume, depends upon the requirements of the system.

Receiver, storage cylinder, air bottle, air cylinder, and flask are all terms used to describe the component of a pneumatic system which provides the functions similar to those provided by the reservoir of a hydraulic system. As described previously in this chapter, the hydraulic reservoir supplies the fluid to the pump and provides a place for the return fluid from the system. In pneumatic systems the receiver stores a volume of gas under the maximum pressure required by the system and supplies it to the system as needed. After the gas is used in the operation of the system, it is exhausted to the atmosphere.

A receiver is usually part of the compressor system. The compressor forces the gas into the receiver where it is stored under pressure. (See chapter 8 for detailed information concerning air compressors.) This receiver may provide gas under pressure directly to pneumatic systems or may be used to charge (fill) other receivers, such as cylinders, bottles, etc., which are, in turn, used to furnish gas to the pneumatic systems.

Receiver is the term usually associated with ground and shipboard pneumatic systems that employ a compressor as part of the system. The receiver is usually located near the compressor and is considered as part of the compressor system.

The receiver acts as a storage tank and also a supply tank. It stores a volume of air under pressure which is provided by the compressor and supplies this compressed air to the pneumatic system or to other receivers. Through the storage of a volume of gas under pressure, the receiver functions to maintain the system at a constant pressure and thereby retards the frequency and length of the start-stop-start cycles of the compressor.

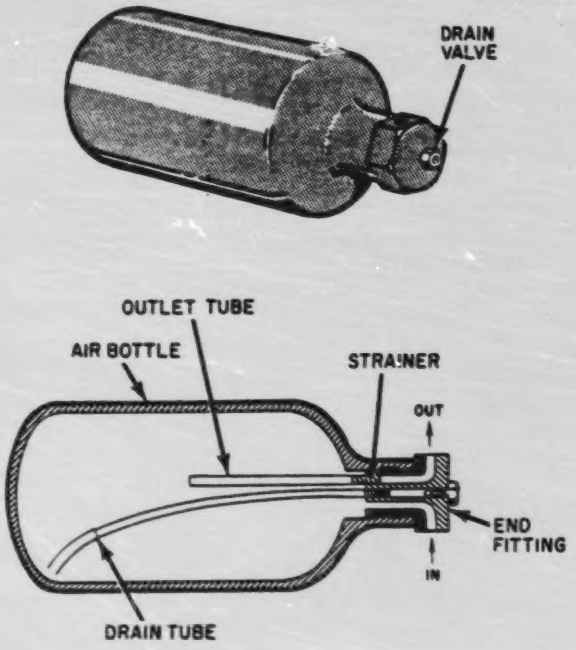
The size and construction of the receiver depend upon the maximum pressure and volume of gas required to efficiently operate the complete system. The receiver is cylindrical in shape and may be mounted either horizontally or vertically, the position and location being dependent on the space available for installation. Vertically mounted receivers should have convex shaped bottoms to permit proper draining of accumulations of moisture, oil, and foreign matter. Each receiver should be fitted with the following accessories and connections:

1. Inlet and outlet connections.
2. Drain connections and valve.
3. Connection for operating line to compressor regulator.
4. Pressure gage.
5. Relief valve.
6. Manhole or handhole plate, depending on the size of the receiver.

The inlet connection is located near the top of the receiver. The outlet connection is located at a point some distance above the bottom of the receiver. This helps to prevent water, oil, and other foreign matter that settles to the bottom of the receiver from entering the system. The line between the compressor and receiver should be kept as short and as free of bends as possible in order to eliminate excessive vibration due to pulsations of air and to reduce friction caused by the flow of air through the lines.

The receivers in aircraft pneumatic systems are referred to as storage cylinders or bottles. The compressed air or nitrogen is stored in these cylinders until required by the actuating system. The cylinders are initially charged with compressed air or nitrogen from an external source. Most systems contain an air compressor which replaces the volume and pressure loss through leakage and system operation.

The storage cylinders are made of steel and may be either spherical or cylindrical in shape. The cylinders are nonshatterable and each is equipped with a moisture drain valve. The valve is incorporated into the end fitting, which is sometimes referred to as a manifold. This fitting also contains the inlet and outlet ports. An example of a storage cylinder used in aircraft pneumatic systems is illustrated in figure 7-5.



FP.88

Figure 7-5.—Compressed gas cylinder for aircraft pneumatic systems.

Cooling of the high-pressure air in the storage cylinder will cause some condensation to collect and settle to the lowest point in the cylinder. To insure positive operation of these systems, the cylinder must be purged of moisture periodically. This is accomplished by slightly opening the moisture drain valve, which connects to the drain tube. As shown in figure 7-5, the other end of the drain tube is positioned at the lowest point in the cylinder. With the drain valve slightly open, any moisture that has accumulated in the cylinder will be forced out of the cylinder through the drain tube.

Cylinders are available in different sizes, the selection of which depends on the requirements of the system. The required size is stipulated by the manufacturer of the system. The unit of measurement to indicate the volume of cylinders is the cubic inch. Cylinders with volumes of 100, 200, and 400 cubic inches are common in aircraft pneumatic systems. The pressure normally required in aircraft pneumatic systems is 3,000 psi.

FILTRATION AND COOLING OF FLUIDS

As pointed out in chapter 3, most malfunctions in fluid power systems may be traced to some type of contaminant in the fluid. For this reason, every effort must be made to prevent contaminants from entering the system and to remove those contaminants which do find their way into the system. Filtration devices are incorporated at key points in fluid power systems to remove those contaminants which, in some way, do enter the system.

Filtration devices for hydraulic systems differ to some extent from those for pneumatic systems and, therefore, are covered separately in the following paragraphs. Cooling devices for hydraulic fluids are also covered in this section. Cooling devices for pneumatic systems are covered under the compressor section of chapter 8.

HYDRAULIC FLUIDS

The importance of keeping hydraulic fluid clean and free of contaminants cannot be overemphasized. Foreign matter in the system can cause excessive wear, increase power loss, clog valves and other components, and substantially increase maintenance and replacement costs. Although great care is taken while servicing, maintaining, and operating hydraulic systems, it is impossible to prevent some foreign matter from entering the system. Some contaminants are built-in; that is, small particles of core sand, weld spatter, metal chips, lint, and abrasive dust, resulting from the manufacturing process, remain in the components when they are installed in the system. Also, tiny particles of metal and sealing materials are deposited in the fluid as a result of the normal wear on valves, pumps, and other components.

FP.89

Figure 7-6.—Typical hydraulic system strainer.

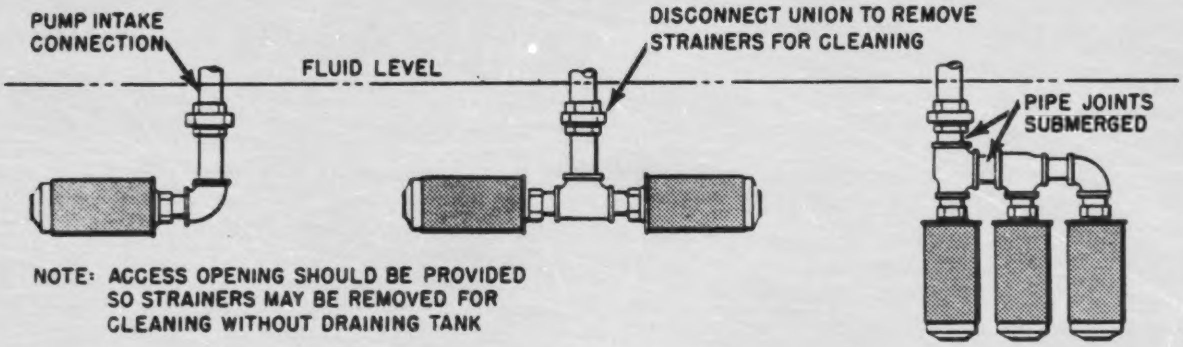
The filtering devices used in hydraulic systems are most commonly referred to as strainers and filters. Since they share a common function, the terms strainer and filter are often used interchangeably. As a general rule, devices used to remove large particles of foreign matter from hydraulic fluids are referred to as strainers, while those used to remove the smallest particles are referred to as filters.

Strainers

Strainers usually consist of a metal frame wrapped with a fine mesh wire screen, or a screening element constructed of varying thicknesses of specially processed wire. A typical strainer is illustrated in figure 7-6.

Strainers do not provide as fine a screening action as filters, but offer less resistance to flow. Therefore, strainers are usually used in pump supply lines where the fluid is in a low-pressure area and restriction of flow would result in starvation of the pump. Strainers are also used in the filler ports of most hydraulic reservoirs.

Various arrangements for using strainers in a pump supply line are illustrated in figure 7-7. If one strainer causes restriction of flow to the pump, two or more may be used in parallel as shown. Since strainers must be removed frequently for cleaning, they need only be hand tightened during installation,


PUMP INTAKE CONNECTION
FLUID LEVEL
DISCONNECT UNION TO REMOVE STRAINERS FOR CLEANING
PIPE JOINTS SUBMERGED
NOTE: ACCESS OPENING SHOULD BE PROVIDED SO STRAINERS MAY BE REMOVED FOR CLEANING WITHOUT DRAINING TANK

FP.90

Figure 7-7.—Various arrangements of hydraulic system strainers.

provided the fittings will remain submerged during the operation of the system. Pump inlet fittings exposed to the atmosphere must be airtight.

Filters

The most common devices incorporated in hydraulic systems to prevent foreign particles and contaminating substances from remaining in the system are referred to as filters. They may be located in the reservoir, in the return line, in the pressure line, or in any other location in the system where the designer of the system decides that they are needed to safeguard the hydraulic system against impurities.

Filters are classified as full flow or proportional flow. In the full flow type filter, all the fluid which enters the unit passes through the filtering element, while in a proportional flow type, only a portion of the fluid passes through the element.

FULL FLOW FILTER.—A full flow filter is illustrated in figure 7-8. This type filter provides a positive filtering action; however, it offers resistance to flow, particularly when the element becomes dirty. For this reason, a full flow filter usually contains a valve, which automatically allows the fluid to bypass the element when the element cannot handle all the flow through the unit.

Hydraulic fluid enters the filter through the inlet port in the body and flows around the filter element inside the filter bowl. Filtering takes place as the fluid passes through the filtering element and into the hollow core, leaving the dirt and impurities on the outside of the filter element. The filtered fluid then flows from the hollow core through the outlet port and into the system.

The bypass pressure relief valve in the body allows the fluid to bypass the filter element and pass directly through the outlet port in the event that the filter element becomes clogged. In most filters of this type, the relief valve is set to open when the differential in pressure exceeds 50 psi. For example, if the pressure at the filter inlet port is 90 psi, and the pressure at the outlet port drops below 40 psi, the relief valve will open and allow the fluid to bypass the element. Additional information concerning the operation of relief valves is presented in chapter 10 of this manual.

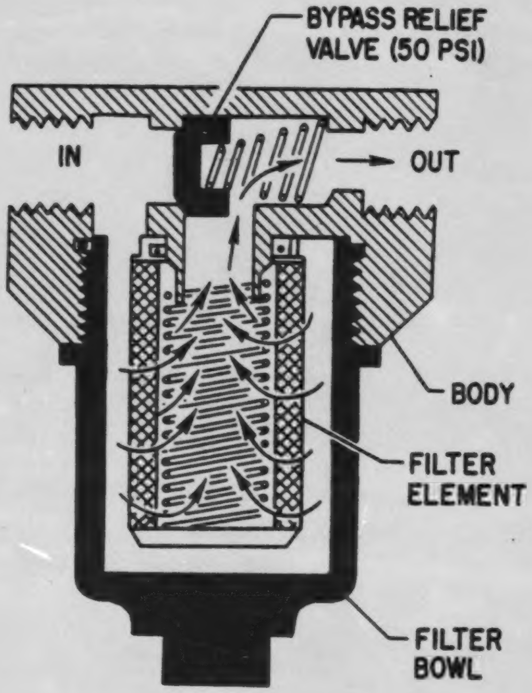


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Figure 7-8.—Full flow hydraulic filter.

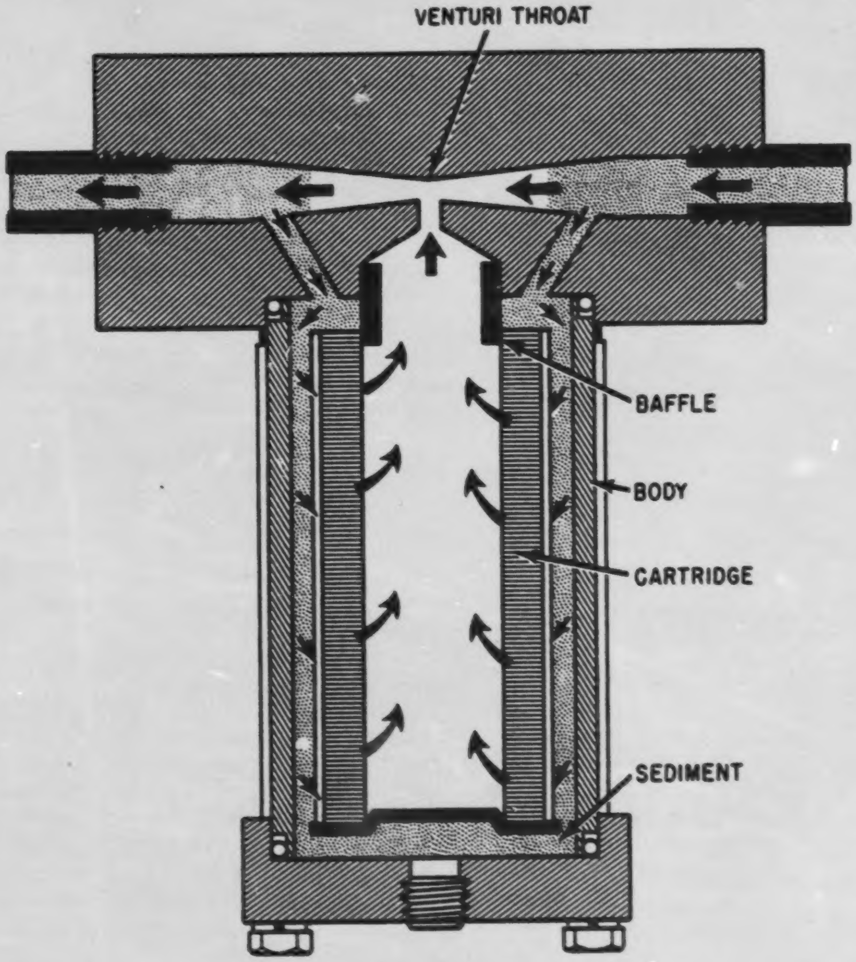
Some nonbypassing full flow filters are equipped with a contamination indicator which operates under the principle of difference in pressure entering the element and pressure after it leaves the element. As contaminating particles collect on the filter element, the differential pressure across the element increases. When the increase in pressure reaches a specific value, an indicator (usually in the filter head) pops out, signifying that the filter element must be cleaned or replaced. A low-temperature lockout feature is incorporated in most types of contamination indicators to prevent actuation below 20° F, thus eliminating the possibility of false indications due to cold weather.

Filter elements used in connection with a contamination indicator are not normally removed or replaced until the indicator is actuated. This decreases the possibility of system contamination from the outside sources due to unnecessary handling.

The use of the nonbypassing type filter eliminates the possibility of contaminated fluid passing the filter element and contaminating the entire system. This type filter will minimize the necessity for flushing the entire system and lessen the possibility of failure of pumps and other components in the system.

A bypass relief valve is incorporated in some filters equipped with the contamination indicator. If the filter element in this type is not replaced when the indicator signifies, the filter element continues to collect foreign particles. The pressure differential between the inlet and outlet ports will continue to increase until the bypass valve opens and directs fluid through the filter element bypass. This is similar to that of the bypass valve of the filter illustrated in figure 7-8.

PROPORTIONAL FLOW FILTER.—Although the full flow filter is the most common type used in hydraulic systems, some systems use the proportional flow filter. A cutaway view of the proportional flow filter is illustrated in figure 7-9. This type filter operates on the venturi



FP.92

Figure 7-9.—Proportional flow hydraulic filter.

principle. (See glossary). As the fluid passes through the venturi throat a drop in pressure is created at the narrowest point. A portion of the fluid flowing toward and away from the throat of the venturi flows through the passages into the body of the filter. A fluid passage connects the hollow core of the filter with the throat of the venturi. Thus, the low pressure area at the throat of the venturi causes the fluid under pressure in the body of the filter to flow through the filter element, through the hollow core, into the low pressure area, and then return to the system. Although only a portion of the fluid is filtered during each cycle, constant recirculation through the system will eventually cause all the fluid to pass through the filter element. Figure 7-9 shows the direction of flow from right to left; however, this type filter provides filtering for either direction of flow.

Filter Elements

The effectiveness of any filter is measured by the degree of filtration it produces. Degree of filtration means that a specific filter element will, when new and clean, stop a certain percentage of the particles which measure a certain size or larger while the fluid is operating under its designed flow conditions.

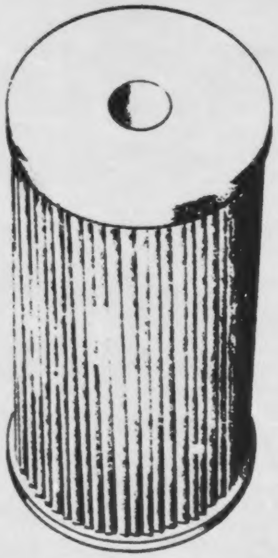
The unit of measurement used in expressing the degree of filtration is the micron. A micron equals one-millionth of a meter, or 0.00004 inch. For comparison value, consider that the normal lower level of visibility to the naked eye is approximately 40 microns. (A grain of table salt is about 100 microns in size; the thickness of a human hair is about 70 microns; and a grain of talcum powder is about 10 microns in size.)

Some hydraulic systems require a much finer degree of cleanliness than others. This is due to the closer tolerances required in some systems, such as the precisely mated parts in the servomechanisms of missiles. Some systems only require that 98 percent of the particles over 100 microns in size are removed, while other systems require that 100 percent of the particles measuring 2 microns are removed. The degree of filtration of a filter depends on the material and design of the filter element.

Filter elements are made of various materials, such as clay, plastic, fuller's earth, cellulose paper (micronic), and metal. Some of the different types of filter elements are described in the following paragraphs.

FULLER'S EARTH.—Fuller's earth is claylike material and is used in the purification of mineral and vegetable base oils. It produces a fine degree of filtration; however, its use as a filtering element in present day hydraulic systems is limited. Filters employing fuller's earth or activated clay should not be used with hydraulic fluids containing additives, because such filters may remove the additives as well as the impurities.

MICRONIC.—Micronic, a term derived from the word micron, could be used to describe any filter element. Through usage, this term has become associated with a specific filter with a filtering element made of a specially treated cellulose paper. The paper is formed in vertical convolutions (wrinkles) and is made in a cylindrical pattern. (See fig. 7-10.) A spring in the hollow core of the element holds the element in shape.



FP.93

Figure 7-10.—Micronic filter element.

This type element is designed to prevent the passage of 99 percent of solids greater than 10 microns in size. The element in the full flow filter illustrated in figure 7-8 is of this design.

The element is normally thrown away when removed. It is replaced at periodic intervals in accordance with the applicable technical instructions. The element is replaced in the following manner:

1. Relieve system pressure.
2. Remove the bowl from the filter body. (In some systems, such as aircraft hydraulic systems, the bowl is safetywired to the body and the wire must be cut for removal.)
3. Remove the filter element from the filter body with a slight rocking motion. Do not twist the element.
4. Replace the element with a new one whenever possible. If a new element is not available, the old element may be cleaned, inspected, and reinstalled.

NOTE: A used micronic filter may be cleaned by masking the element outlet and rinsing it with a cleaning solvent that is compatible with the fluid used in the system. After cleaning, inspect carefully to insure that there are no holes in the paper walls of the element.

5. Replace all old O-ring packings and backup washers with new ones.
6. Reinstall the bowl onto the body. Do not tighten the bowl excessively; handtight is usually sufficient.
7. Pressurize the system and check the filter assembly for leaks. Safetywire if required.

SINTERED BRONZE.—The sintered bronze element consists of minute bronze balls joined together as one solid piece, but still remaining porous. The process of joining the balls is known as the sintered process. This element is capable of filtering particles greater than 5 microns, or approximately 0.0002 inch in size.

The operation of the sintered bronze filter is very similar to that of the micronic filter. Most sintered bronze filters are equipped with either the bypass relief valve or the contamination indicator described in this chapter.

The sintered bronze element may be cleaned, tested, and reused a maximum of four times at which time it must be replaced. Cleaning of the element is accomplished by dipping it in a cleaning solvent that is compatible with the liquid used in the system and allowing the solvent to flow through the element. The element should then be dried by blowing dry, filtered air through the element from the inside to the outside.

STAINLESS STEEL.—Stainless steel filter elements are used in the hydraulic systems of many of the Navy's most modern aircraft. This type element is similar in construction to the sintered bronze element described previously. The design is usually a corrugated sintered stainless steel mesh such as the magnified cross section shown in figure 7-11. One manufacturer calls this type a "Dutch Twill" pattern. Elements of this type are capable of filtering 95 percent of 5- to 10-micron particles and 100 percent of 25-micron particles from the fluid. The curved passages of the filter element, through which the fluid passes, limit the length of the particles that pass through the element. Most filters that use the stainless steel element are equipped with the contamination indicator described earlier in this chapter.

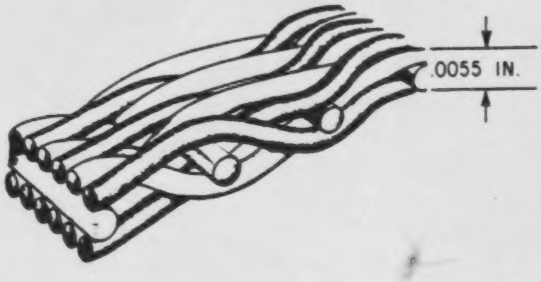


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Figure 7-11.—Cross-section of a stainless steel filter element.

Stainless steel elements are of the reusable type. The specific time limit on the usage of this type filter differs with the type of system and equipment. Also, special equipment and procedures are required in the cleaning of this type element. For these reasons, the applicable technical instructions must be consulted when maintenance is performed on this type filter element.

Some hydraulic systems have magnetic filters installed at strategic points. Filters of this type are designed primarily to trap any magnetic particles that may be in the system.

Temperature Control

Hydraulic systems operate most efficiently when the fluid temperature is held within a specific range. All hydraulic fluids are designed to provide minimum flow resistance with suitable sealing properties when the fluid temperature is maintained within the correct range. The recommended temperature range varies with different types of fluid; for example, the recommended operating temperature of one type fluid is -65° F to +275° F, while the recommended range of another type is -25° F to +140° F. Operating at a temperature below that of the recommended range results in sluggish movement of the fluid through orifices and other restrictions in the lines and components.

Temperatures higher than the desired level reduce the lubricating characteristics of the fluid and also cause the fluid to break down, forming sludge and other contaminants. Heat will also cause sealing materials to become brittle and close-fitting precision parts of valves and other components to seize. In addition, high temperatures lower the viscosity of the fluid which, in turn, reduces the efficiency of the pump.

Excessively low fluid temperatures are caused primarily by external sources, for example, hydraulic systems operating in extremely cold climates. External sources are also a major cause of excessively high fluid temperatures. However, in addition to the effects of external temperature, the friction, resulting from fluid flowing through components and long lengths of lines, creates heat.

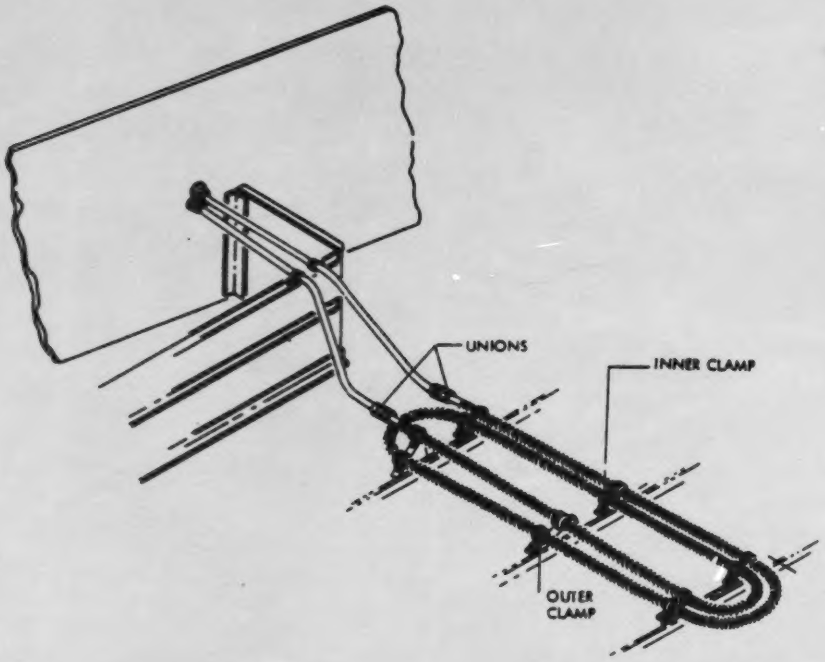
In most systems, temperature control is not a problem. Although slightly cold temperatures may cause sluggish action of the fluid when first operating a system after it has been idle for a period of time, the friction resulting from the flow of fluid through the system will usually increase the temperature of the fluid to the desired level. As discussed previously in this chapter, most of the heat is dissipated from the fluid as it circulates through the reservoir. In some systems, however, it is necessary to control the fluid temperature. For example, in extremely cold atmospheric conditions, some means must be provided to heat the fluid. In some systems, it is impossible to incorporate a reservoir large enough to dissipate enough heat to provide satisfactory cooling. These systems require some means to cool the fluid.

The component used to heat or cool liquids is usually referred to as a heat exchanger. Air, steam, or another liquid is usually used as the heat exchange medium. Some systems use an electric heat probe, immersed in the fluid within the reservoir for heating the fluid.

There are several different designs of heat exchangers. One type is similar in design to the automobile radiator in which the fluid flows through small tubes in the core, and air is forced through the honeycomb material around the core to cool the fluid. Another type is the shell-and-tube heat exchanger. This type consists of a cylindrical metal shell containing a bundle of metal tubes. The hydraulic fluid flows through the tubes while the heating or cooling medium flows through the shell around the tubes. This type can use steam or hot water as a heating medium. For cooling, water or refrigerated liquid may be used.

Fin tubing is another type of heat exchanger used in some hydraulic systems. The fins help to dissipate the heat from the fluid flowing through the line. Air may be forced around the lines to increase the cooling effect. The fin tubing type heat exchanger can also be immersed in a heating or cooling medium. An example of this type installation is illustrated in figure 7-12. In this installation, several loops of the fin tubing are mounted in one of the fuel cells of an aircraft. Fluid enters the inlet coupling, flows through the fin wall tubing, through the outlet coupling, and then returns to the reservoir. The heat of the fluid flowing through the heat exchanger is absorbed by the fins and the fuel.

Another type of radiator heat exchanger is illustrated in figure 7-13. This type is used in several models of aircraft to cool the hydraulic fluid. Like the fin tubing heat exchanger illustrated in figure 7-12, the radiator type utilizes fuel as a cooling medium. This heat exchanger is used to cool the fluid for two separate hydraulic systems. In addition, it has a fuel filter incorporated which filters the fuel supply to the engine.



FP.95

Figure 7-12.—Fin tubing heat exchanger.

The radiator unit consists of a cylindrical housing containing two cooling coils of 1/2-inch aluminum alloy tubing and a replaceable fuel filter element. The cooling coil for one hydraulic system is installed in the right-hand end of the housing; the cooling coil for the other hydraulic system and the filter element are installed in the left-hand end as viewed in figure 7-13. The housing ends contain fittings for connecting fuel hoses. Threaded fittings, which are secured to the cooling coil ends, serve to connect the hydraulic lines from each system.

In operation, hydraulic fluid returning to the reservoir is directed through the applicable system cooling coil where sufficient heat is transferred to the engine fuel fo maintain the temperature of the hydraulic fluid at the desired level. Should the cooling coils become clogged, each hydraulic system is equipped with a bypass relief valve which opens and bypasses fluid around the coil and directly to the reservoir.

PNEUMATIC GASES

Clean, dry gas is required for the efficient operation of pneumatic systems. Due to the normal conditions of the atmosphere, free air seldom satisfies these requirements adequately. The atmosphere contains dust and impurities in various amounts, depending on the locality. Also, the atmosphere generally contains a substantial amount of moisture in vapor form.

Solids such as dust, rust, or pipe scale in pneumatic systems may lead to excessive wear and failure of components, and in some cases prevent the pneumatic devices from operating. Moisture is also very harmful to the system. It washes lubrication from moving parts, thereby aiding corrosion and causing excessive wear of components. Moisture will also settle in low spots in the system and freeze during cold weather, causing stoppage of the system or rupture of lines.

As discussed in chapter 3, the use of nitrogen decreases these hazards to some

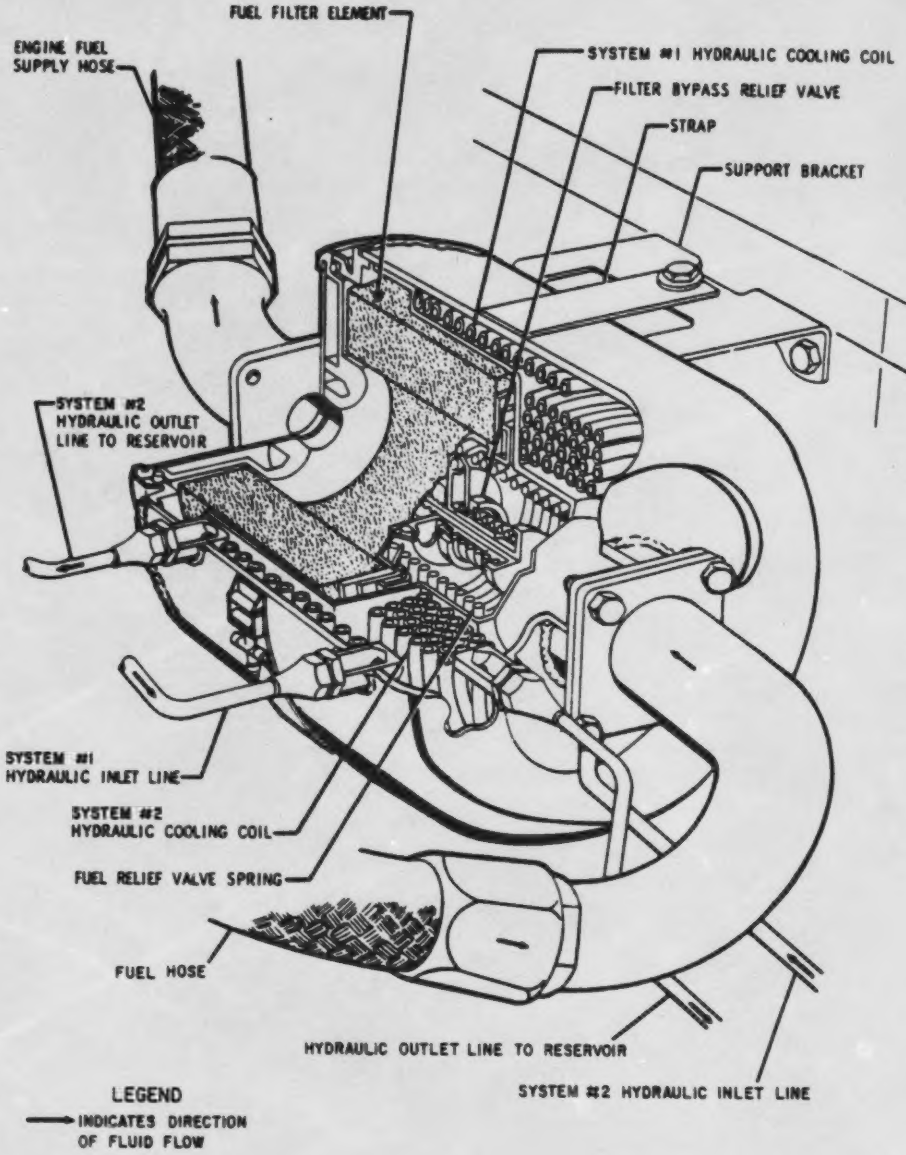

FUEL FILTER ELEMENT
ENGINE FUEL SUPPLY HOSE
SYSTEM #1 HYDRAULIC COOLING COIL
FILTER BYPASS RELIEF VALVE
STRAP
SUPPORT BRACKET
SYSTEM #2 HYDRAULIC OUTLET LINE TO RESERVOIR
SYSTEM #1 HYDRAULIC INLET LINE
SYSTEM #2 HYDRAULIC COOLING COIL
FUEL RELIEF VALVE SPRING
FUEL HOSE
HYDRAULIC OUTLET LINE TO RESERVOIR
SYSTEM #2 HYDRAULIC INLET LINE
LEGEND
→ INDICATES DIRECTION OF FLUID FLOW

Figure 7-13.—Radiator type heat exchanger.

FP.96

extent. However, it is not economically feasible to use nitrogen, except in small systems.

An ideal filter would remove all dirt and moisture from a pneumatic system without causing a pressure drop in the process. Obviously, such a condition can only be approached; it cannot be attained.

Removal of Solids

The removal of solids from the gas of pneumatic systems is generally accomplished by screening (filtering), centrifugal force, or a combination of the two. In some cases, the removal of moisture is accomplished in conjunction with the removal of solids.

Some types of air filters are similar in design and operation to the hydraulic filters discussed earlier in this chapter. Some materials used in the construction of elements for air filters are woven screen wire, steel wool, fiber glass, and felt fabrics. Elements made of these materials are often used in the unit that filters the air as it enters the compressor. They are used in the same manner as carburetor filters on automobile engines. These filters must be checked frequently for the accumulation of foreign matter and the element cleaned or replaced as necessary. If the filter element becomes clogged, the compressor is reduced in efficiency or, in extreme cases, becomes inoperative. Filters of this type are usually designed to remove particles as small as 25 microns.

Porous metal and ceramic elements are commonly used in filters that are installed in the compressed air supply lines. These filters also use a controlled airpath to provide some filtration. Internal design causes the air to flow in a centrifugal path within the bowl. (See fig. 7-14.) Heavy particles and water droplets are thrown out from the airstream and drop to the bottom of the bowl. The air then flows through the filter element, which filters out most of the smaller particles. This type filter is designed with a drain valve at the bottom of the bowl. When the valve is opened with air pressure in the system, the accumulation of solids and water will be blown out of the bowl. Many air filters of this type have transparent bowls so that the accumulation of impurities can be seen. Some units are provided with automatic drainage.

An air filter that employs moving mechanical devices as an element is illustrated in figure 7-15. As the compressed air passes through the filter the force revolves a number of multiblade rotors at high speed. Moisture and dirt are caught on the blades of the rotors. The whirling blades hurl the impurities by centrifugal force to the outer rims of the rotors and to the inner walls of the filter housing. Here, contaminating matter is out of the airstream and falls to the bottom of the bowl where it must be drained at periodic intervals.

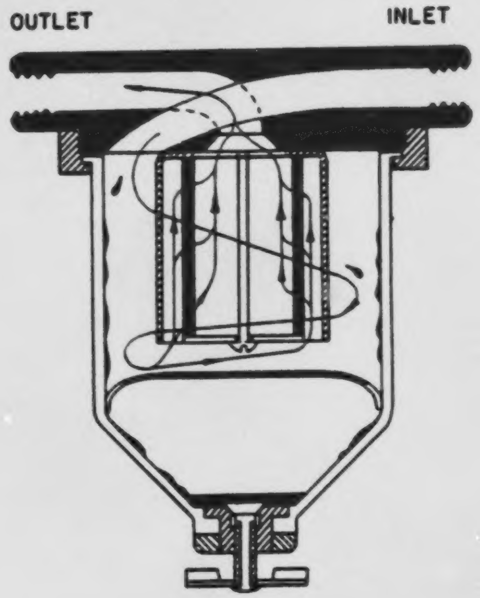


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Figure 7-14.—Air filter.

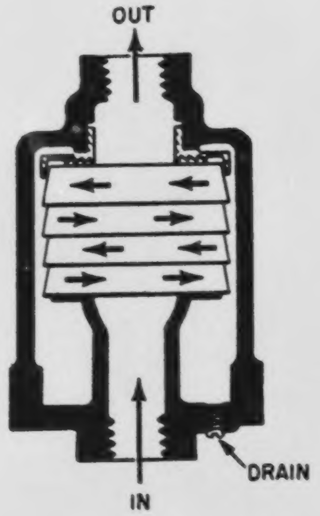

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Figure 7-15.—Air filter using rotating blades as element.

Removal of Moisture

When it enters the compressor, air contains a certain amount of moisture in vapor form.

When it enters the compressor, air contains a certain amount of moisture in vapor form. During the compression process, the temperature and pressure of the air increase and the moisture remains in vapor form. If the moisture would remain in vapor form it would have very little effect on the system. However, as the compressed air cools, the moisture vapor condenses into water. When it is in this condensed state, moisture causes corrosion and rust, dilutes lubricants, and may freeze in the lines and components.

Since cooling of the compressed air causes the moisture to condense, cooling devices are installed immediately after the compressor before the air enters the receiver and flows on into the system. There is a water separator fitted on the discharge side of the cooler. As the air is cooled, the moisture condenses and is removed from the system as the air passes through the water separator. The separators are of a variety of designs. The removal of moisture is accomplished by centrifugal force, impact, or sudden changes in velocity of the airstream. Many water separators are similar in design and operation to the filters illustrated in figures 7-14 and 7-15.

Chemical driers are incorporated in some pneumatic systems. Their purpose is to absorb any moisture that may collect in the lines after the water separator. Air drier, dehydrator, air purifier, and desiccator are all terms used by different manufactures to identify these components.

One type of chemical drier is illustrated in figure 7-16. This unit consists of the housing, a cartridge containing a chemical agent, a filter (sintered bronze), and a spring. Various types of absorbent chemicals are used by the different manufacturers in the construction of the cartridges. To insure proper filtering, the air must pass through the drier in the proper direction. The correct direction of flow is indicated by an arrow and the word FLOW printed on the side of the cartridge. The cartridge must be replaced at intervals specified by the applicable technical instructions.7-18

ACCUMULATOR

Hydraulic accumulators are incorporated in some hydraulic systems to store a volume of liquid under pressure for subsequent conversion into useful work. This potential energy may be the result of gravitation, the elasticity of springs, or the compressibility of gases. In addition to a source of fluid supply, accumulators also provide several other useful functions. These functions are described in the last part of this section under "Applications."

DEAD-WEIGHT ACCUMULATORS

The dead-weight or gravity type accumulator represents the earliest form of accumulators and is generally used as a single unit to operate a multiple battery of machines.

This accumulator consists of a vertical cylinder with a smoothly machined bore into which is fitted a piston with suitable packing. (See fig. 7-17.) A platform is mounted on the top of the piston on which is placed a high density material, such as concrete blocks, metal, or stone. The force of gravity provides energy to force the liquid from the cylinder into the hydraulic system. The main advantage of this type accumulator is that the pressure is constant regardless of the amount of liquid in the cylinder, since the weight of the material on top of the piston remains constant. The main disadvantage of the dead-weight accumulator is its cumbersome size and weight.

SPRING-OPERATED ACCUMULATOR

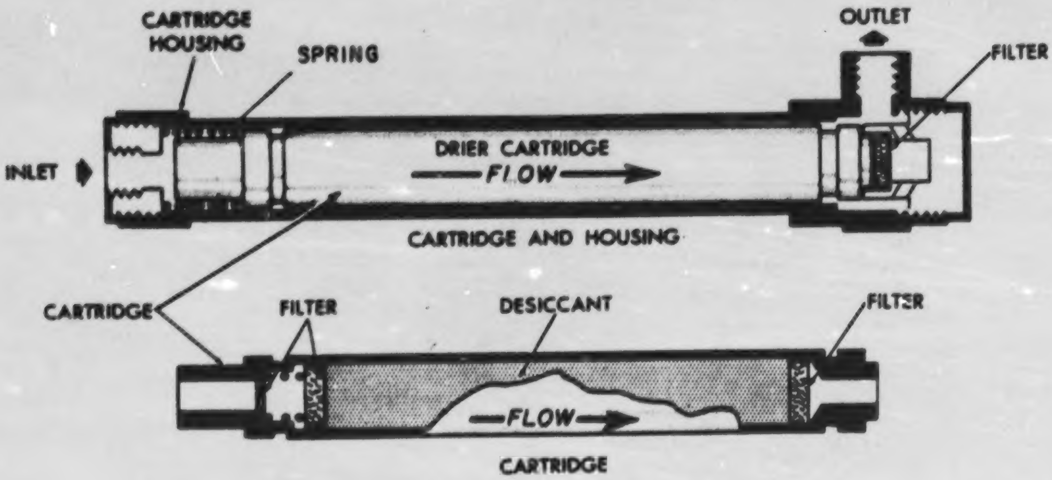
The spring-operated accumulator is similar in principle and design to the dead-weight type, except that spring tension supplies the force. Figure 7-18 depicts two examples of spring-operated accumulators.

The load characteristics of a spring are such that the energy storage depends on the force required to compress the spring. The uncompressed length of the spring represents zero energy storage.

In this type accumulator the compression resulting from the maximum installed length of the spring or springs should provide the minimum pressure required of the liquid in the cylinder assembly. As liquid is forced into the cylinder, the piston is forced upward and the spring or springs are further compressed, thus providing a reservoir of potential energy for later use.

AIR-OPERATED ACCUMULATORS

The air-operated accumulator is often referred to as a pneumatic or hydropneumatic



FP.99

Figure 7-16.—Chemical drier.

accumulator. This type accumulator utilizes compressed gas (usually air or nitrogen) to apply force to the stored liquid. Air-operated accumulators are classified as either nonseparator or separator types.

Nonseparator Type

In the nonseparator type accumulator, no means are provided for separating the gas from the liquid. It consists of a fully enclosed cylinder, mounted in a vertical position, containing a liquid port on the bottom and a pneumatic charging port at the top. Figure 7-19 depicts a nonseparator type air-operated accumulator.

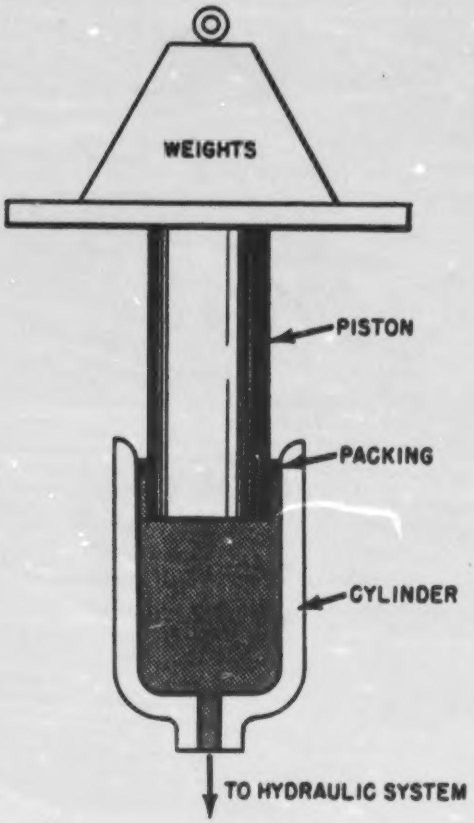
To prevent gas from entering the system, there must be some liquid trapped in the bottom of the cylinder when this type accumulator is placed in service. Nitrogen or compressed air is then charged into the top of the cylinder until the pressure is equivalent to the minimum system requirements. As the system forces liquid into the bottom of the cylinder, the gas is further compressed and this compressed gas is then used as the energy medium. Only about 70 percent of the accumulator liquid is used in the system, as the remaining space must act as a separator to prevent the gas from entering the hydraulic system.

Separator Type

In the separator type of air-operated accumulator, a means is provided to separate the gas from the liquid. Three types of separators are bladder or bag, diaphragm, and piston (cylinder).

BLADDER OR BAG.—Figure 7-20 illustrates one version of an air-operated accumulator of the bladder type. This accumulator derives its name from the shape of the synthetic rubber bladder or bag which separates the liquid and gas within the accumulator. The accumulator consists of a seamless high-pressure shell, cylindrical in shape with domed ends. The bladder is fully enclosed in the shell and is molded to an air stem in the upper end of the shell, as it appears in the illustration. The air stem contains a high-pressure air valve. The bottom end of the shell is sealed with a special plug assembly containing the liquid port and usually a safety feature, which makes it impossible to disassemble the accumulator with pressure in the system.

The bladder is larger in diameter at the top (near the air valve) and gradually tapers to a smaller diameter at the bottom. The synthetic rubber is thinner at the top of the bladder than at the bottom. The operation of the accumulator is based on Barlow's formula



FP.100
Figure 7-17.—Dead-weight accumulator.

for hoop stress which states: the stress in a circle is directly proportional to its diameter and wall thickness. This means that for a certain thickness, a large diameter circle will stretch faster than a small diameter circle; or for a certain diameter, a thin wall hoop will stretch faster than a thick wall hoop. Thus, the bladder will stretch around the top at its largest diameter and thinnest wall thickness, and then will gradually stretch downward and push itself outward against the walls of the shell. As a result the bladder is capable of squeezing out all the liquid from the accumulator. Consequently, the bladder accumulator has a very high volumetric efficiency. In other words, this type accumulator is capable of supplying a large percentage of the stored fluid to do work.

DIAPHRAGM.—Although there are several different modifications of the diaphragm accumulator, it is usually spherical in shape. Figure 7-21 illustrates an example of this type. The shell is constructed of two metal hemispheres, which are either screwed or bolted together. The fluid and gas chambers are seperated by a snythetic rubber diaphragm. An air valve for pressurizing the accumulator is located in the gas chamber end of the sphere, and the liquid port to the hydraulic system is located on the opposite end of the sphere. This accumulator operates very similar to the bladder type.

CYLINDER.—A cylinder type accumulator is illustrated in figure 7-22. This accumulator contains a free-floating piston, which separates the gas and liquid chambers. The cylindrical accumulator consists of a barrel assembly, a piston assembly, and two end cap assemblies. The barrel assembly houses the piston and incorporates provisions for securing the end caps. The piston contains two packings. A small drilled passage from the liquid side of the piston to a point between the two seals provides for lubrication of the seal on the air chamber side.

Operation

In the operation of pneumatic type accumulators, the compressed air chamber is inflated with air or nitrogen to a predetermined pressure that is somewhat lower than system pressure. This pressure is stipulated by the system manufacturer. This initial charge of gas is referred to as accumulator preload.

As an example of accumulator operation, assume that an accumulator is designed for a preload of 600 psi in a 1,500 psi system.

The hydraulic system pressure should be zero when the initial charge of 600 psi preload is introduced into the air chamber of the accumulator. Some accumulators are equiped with air pressure gages for checking the preload. When the accumulator is not so equipped, a suitable high-pressure air gage must be installed at the air preload fitting for this purpose. As air pressure is applied through the air pressure port, it moves the separator (bladder, diaphragm, or piston) toward the opposite end. The 600 psi preload moves or stretches the separator to the extent that the

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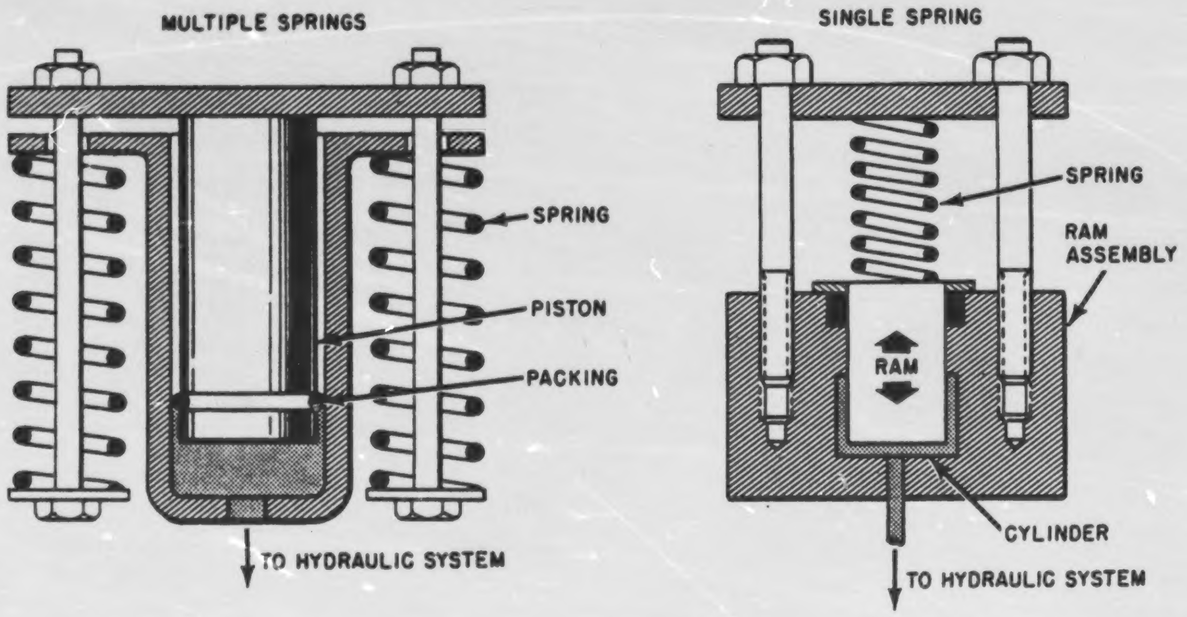

FP.101

Figure 7-18.—Spring-operated accumulators.

volume of gas under pressure completely fills the entire shell of the accumulator. After the accumulator has been preloaded to 600 psi, the hydraulic system is operated and the pump will force fluid against the separator of the accumulator. The system pressure must increase to a pressure greater than 600 psi before the hydraulic fluid can move the separator. Thus, at 601 psi the separator will start to move within the accumulator, compressing the gas as it moves. At 1,500 psi, the gas is compressed to the extent that it occupies less than one-half the space that it did at 600 psi. The remaining space stores a volume of liquid under pressure for subsequent demands of the system.

When actuation of hydraulic circuits lowers system pressure, it is evident that the compressed gas will expand against the separator, forcing liquid from the accumulator, thus supplying an instantaneous supply of liquid to the hydraulic system.

Pneumatic accumulators should be visually examined for indications of external hydraulic leaks periodically. They should then be examined for external air leaks by brushing the exterior with soapy water, which will form bubbles where the air leaks occur.

The air valve assembly should be loosened to examine the accumulator for internal leaks. If liquid comes out of the air valve, it indicates a leak in the separator. This is caused by a ruptured bladder or diaphragm, or by faulty packing on the piston type. As a result the accumulator must be removed, repaired, and reinstalled.

Before removing an accumulator from the system for repair, all internal pressure must be relieved. The pumps must be turned off and system pressure relieved by actuating some part of the system until all pressure is dissipated. The preload is released by loosening the swivel nut on the air filler valve until all air is completely exhausted, then remove the valve.

Applications

Many of the present day hydraulic systems are equipped with one or more accumulators. The storage of liquid under pressure serves

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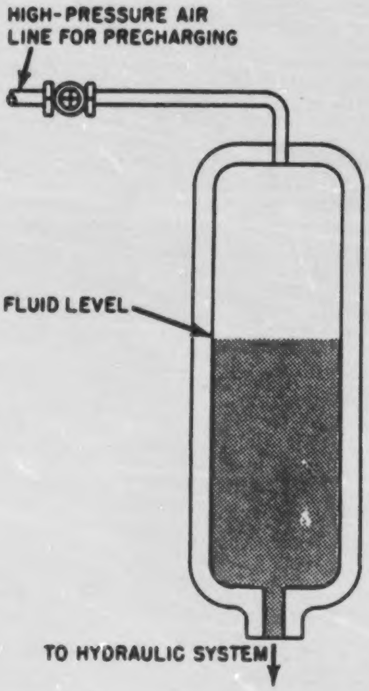


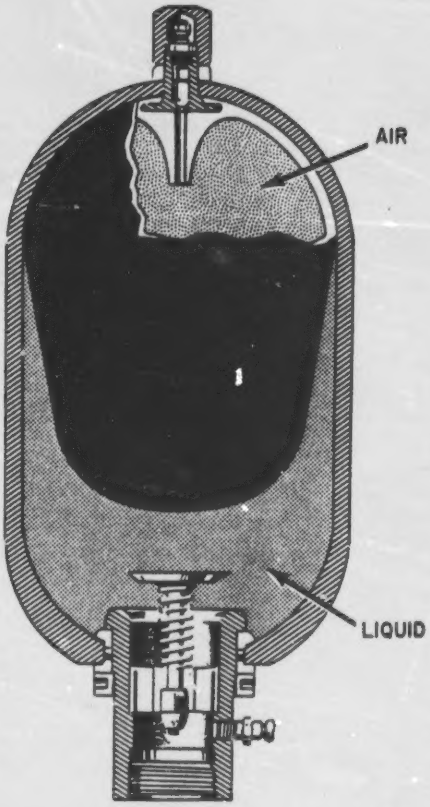
FP.102
Figure 7-19.—Air-operated accumulator (nonseparator type).

several purposes in hydraulic systems, some of which are described in the following paragraphs. Some of the hydraulic systems illustrated and described in chapter 13 of this manual show the applications of accumulators and their relationship to other components in the system.

LEAKAGE COMPENSATOR.—In some operations it is necessary to maintain the hydraulic system under a controlled pressure for long periods of time. It is very difficult to maintain a closed system without some leakage, either external or internal. Even a small leak can decrease the required pressure. By the proper use of an accumulator, this leakage can be compensated for and the pressure maintained within an acceptable range for long periods of time. In the same manner, the accumulator can compensate for thermal expansion and contraction of the liquid due to variations in temperature.

SHOCK ABSORBER.—A liquid, flowing at a high velocity in a pipe, will create a backward surge when stopped suddenly by the closing of a valve and thus develop instantaneous pressures two and three times the operating pressure of the system. This shock will result in objectional noise and vibration which can cause considerable damage to piping, fittings, and components. The incorporation of an accumulator will enable such shock and surges to be absorbed or cushioned by the entrapped gas, thereby reducing their effects. The accumulator will also dampen pressure surges caused by the pulsating delivery from the pump.

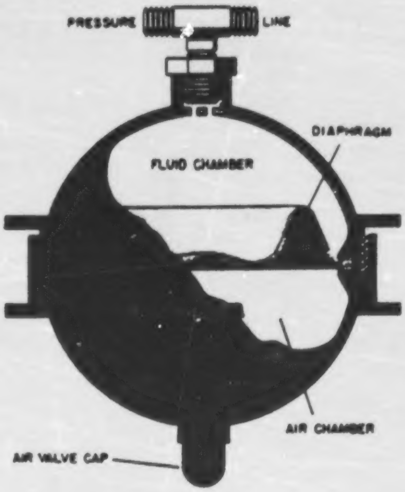
AID TO PUMP.—There are times when most hydraulic systems require large volumes of liquid for short periods of time. This is due to large cylinders or the necessity of operating two or more circuits simultaneously. It is



FP.103
Figure 7-20.—Air-operated bladder type accumulator.

not economical to incorporate a pump of such capacity in the system for only intermittent usage to supply these applications, particularly if there are sufficient intervals during the working cycle for an accumulator to store up a volume of liquid to aid the pump during these peak demands.

EMERGENCY POWER SUPPLY.—The energy stored in an accumulator may be used to actuate a unit in the event of normal hydraulic system failure. For example, in an aircraft hydraulic system, sufficient energy can be stored in the accumulator for several applications of the wheel brakes.


PRESSURE
LINE
DIAPHRAGM
FLUID CHAMBER
AIR CHAMBER
AIR VALVE CAP

FP.104

Figure 7-21.—Diaphragm accumulator.

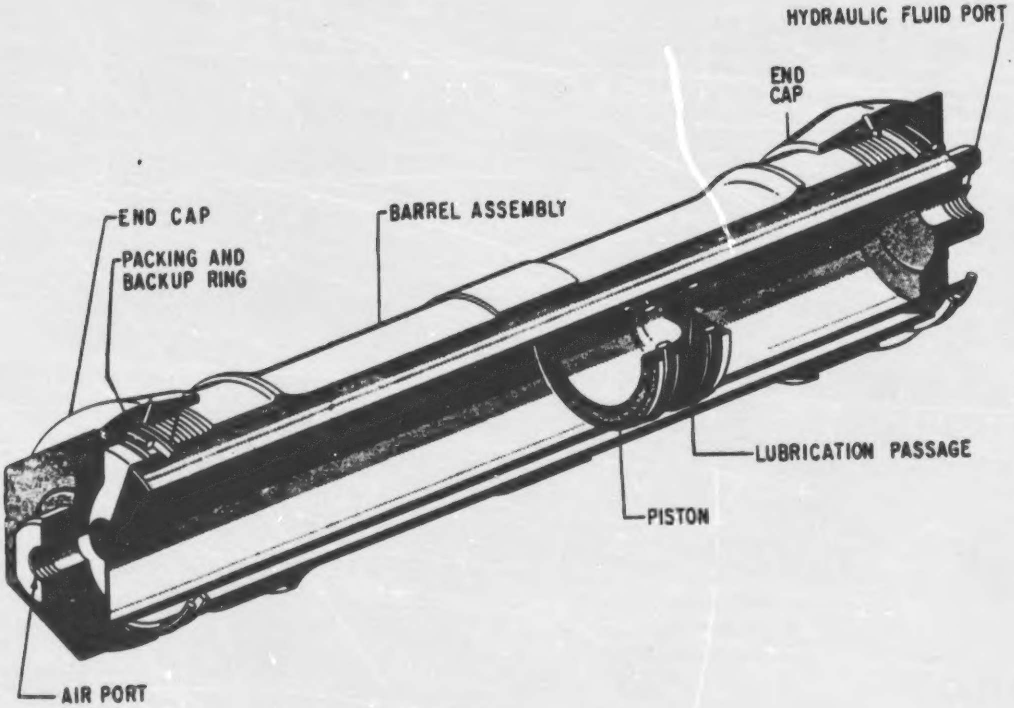

HYDRAULIC FLUID PORT
END CAP
END CAP
PACKING AND BACKUP RING
BARREL ASSEMBLY
LUBRICATION PASSAGE
PISTON
AIR PORT

Figure 7-22.—Cylinder (piston) accumulator. FP.105

CHAPTER 8

PUMPS AND COMPRESSORS

To accomplish work, fluid power systems require some means to provide a flow of fluid. Pumps are utilized to provide this requirement in hydraulic systems. Although the volume and the pressure of a compressed gas provide the flow in pneumatic systems, some means must be utilized to compress the gas. The air compressor is commonly used in pneumatic systems for this purpose and is, therefore, considered the source of power in pneumatic systems. It should be noted that some pneumatic systems do not contain a compressor. In these systems, a container, such as a cylinder or bottle, of compressed gas (air or nitrogen) is connected to the system to provide the power for the system. However, some type of compressor must be used to charge (fill) these containers with the compressed gas. Although pumps and compressors do serve similar functions in their respective systems, the principles of operation and the design differ to some extent. Due to these differences, the two components are discussed separately in this chapter.

PUMPS

Pumps are used for a number of essential services in the Navy. Pumps supply water to the boilers, draw condensation from the condensers, supply sea water to the firemain, circulate cooling water for coolers and condensers, pump out bilges, transfer fuel, supply water to the distilling plants, and serve many other purposes. Although the pumps discussed in this chapter are those used in hydraulic systems, the principles of operation of the different types apply to the pumps used in other systems.

PURPOSE

A hydraulic pump is a device which converts mechanical force and motion into hydraulic energy. Many different sources are used to provide the mechanical power to the pump. Electric motors, air motors, and gasoline engines are all used as a source of power to operate hydraulic pumps. Some pumps are manually operated. Many of the pumps in aircraft hydraulic systems are attached to and driven by the aircraft engine.

The purpose of a hydraulic pump is to supply a flow of fluid to a hydraulic system. It should be emphasized that a pump does not create pressure, since pressure can be created only by a resistance to the flow. As it provides flow, the pump transmits a force to the fluid. As a result, a pump can produce the flow and force necessary for the development of pressure; however, since it cannot provide resistance to its own flow, a pump, alone, cannot produce pressure. Resistance to flow is the result of a restriction or obstruction in the path of the flow. This restriction is normally the work accomplished by the hydraulic system, but can also be restrictions of lines, fittings, and valves within the system. Thus, the pressure is controlled by the load imposed on the system or the action of a pressure regulating device.

In order for a pump to supply a flow of fluid to the pump outlet and into the system, it must have a continuous supply of fluid available to the inlet port. Atmospheric pressure (discussed in chapter 2) plays an important role in the supply of fluid to the inlet port. If the pump is located at a level lower than that of the reservoir, the force of gravity supplements atmospheric pressure. However, in most systems the pump is located above the reservoir. Aircraft and missiles that operate at high altitudes are equipped with pressurized hydraulic reservoirs (see chapter 7) to compensate for low atmospheric pressure encountered at high altitudes.

As the pump forces fluid through the outlet port, a partial vacuum or low-pressure area

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(often referred to as suction) is created at the inlet port. This low-pressure area contains a pressure lower than the surrounding atmospheric pressure (approximately 14.7 psi at sea level). When the pressure at the inlet port of the pump is lower than the local atmospheric pressure, the atmospheric pressure acting on the fluid in the reservoir forces the fluid into the pump.

PUMP PERFORMANCE

Pumps are normally rated in terms of volumetric output and pressure. The volumetric output is the amount of fluid the pump can deliver to its outlet port in a certain period of time at a given speed. Volumetric output is usually expressed in gallons per minute (gpm). Since changes in pump speed affect volumetric output, some pumps are rated according to displacement. Pump displacement is the amount of fluid the pump can deliver per cycle. Since most pumps use a rotary drive, the displacement is usually expressed in terms of cubic inches per revolution.

As stated previously, a pump does not create pressure. However, the pressure developed by the restriction in the system is a factor that affects the volumetric output of the pump. As the system pressure increases, the volumetric output decreases. This drop in volumetric output is the result of an increase in the amount of internal leakage from the outlet side to the inlet side of the pump. This leakage is referred to as pump slippage and is a factor that must be considered in all pumps. Therefore, most pumps are rated in terms of volumetric output at a given pressure. Some pumps have greater internal slippage than others. This indicates the efficiency of a pump and is usually expressed in percent.

CLASSIFICATION OF PUMPS

Many different methods are used to classify pumps. Terms such as nonpositive displacement, positive displacement, fixed displacement, variable displacement, fixed delivery, variable delivery, constant volume, and others are used to describe pumps. The first two of these terms describe the fundamental division of pumps; that is, all pumps are either of the nonpositive displacement or positive displacement type. Basically, pumps which discharge liquid in a continuous flow are referred to as nonpositive displacement, and those which discharge volumes separated by a period of no discharge are referred to as positive displacement.

Although the nonpositive displacement pump normally produces a continuous flow, it does not provide a positive seal against slippage and, therefore, the output of the pump varies as system pressure varies. In other words, the volume of fluid delivered for each cycle is dependent upon the resistance offered to the flow. This type pump produces a force on the fluid that is constant for each particular speed of the pump. Resistance in the discharge line produces a force in the opposite direction. When these forces are equal, the fluid is in a state of equilibrium and does not flow.

If the outlet of a nonpositive displacement pump is completely closed, the discharge pressure will increase to the maximum for that particular pump at a specific speed. Nothing more will happen except that the pump will churn the fluid and produce heat.

In contrast to the nonpositive displacement pump, the positive displacement pump provides a positive internal seal against slippage. Therefore, this type pump delivers a definite volume of fluid for each cycle of pump operation, regardless of the resistance offered, provided the capacity of the power unit driving the pump is not exceeded. If the outlet of a positive displacement pump is completely closed, the pressure would instantaneously increase to the point at which the unit driving the pump would stall or something would break.

Positive displacement pumps are further classified as fixed displacement or variable displacement. The fixed displacement pump delivers the same amount of fluid on each cycle. The output volume can be changed only by changing the speed of the pump. When a pump of this type is used in a hydraulic system, a pressure regulator (unloading valve) must be incorporated in the system. A pressure regulator or unloading valve is used in a hydraulic system to control the amount of pressure in the system and to unload or relieve the pump when the desired pressure is reached. This action of a pressure regulator keeps the pump from working against a load when the hydraulic system is at maximum pressure and not functioning. During this time the pressure regulator

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bypasses the fluid from the pump back to the reservoir. (See chapter 10 for more detailed information concerning pressure regulators.) The pump continues to deliver a fixed volume of fluid during each cycle. Such terms as fixed delivery, constant delivery, and constant volume are all used to identify the fixed displacement pump.

The variable displacement pump is constructed in such a manner that the displacement per cycle can be varied. The displacement is varied through the use of an integral controlling device which controls the working relationship of the internal operating mechanisms of the pump. Some of these controlling devices are described later in this chapter.

Pumps may also be classified according to the specific design used to create the flow of fluid. Practically all hydraulic pumps fall within three classifications of design--centrifugal, rotary, and reciprocating. These classifications are best illustrated in the following discussion of principles of operation.

CENTRIFUGAL PUMPS

There are several different types of centrifugal pumps, but they all operate on the same principle. In each case, the operation depends upon the centrifugal force produced by the rotation of an impeller at high speeds. This force, in turn, imparts a high velocity to the fluid delivered through the pump.

Centrifugal force is based on the principle of inertia. Although inertia is discussed in detail in chapter 2, for convenience, the basic law is repeated here: "A body at rest tends to remain at rest, and a body in motion tends to continue in motion with the same velocity and in the same direction."

Many illustrations of centrifugal force could be cited. A familiar one is the tendency of an automobile to skid towards the outside of the curve when rounding a corner at high speed. For the same reason the occupants of the automobile are forced against the outer side. An example of centrifugal force, helpful for the understanding of centrifugal pumps, can be found if one imagines a man whirling a bucket of water rapidly around in a circle over his head. If he whirls the bucket rapidly enough, the outward or centrifugal force will hold the water against the bottom of the bucket and will not spill, even when the bucket is upside down. By whirling the bucket very rapidly, a force many times the force of gravity can be developed.

To understand the application of this example to a centrifugal pump, assume that a number of bottomless buckets rotating about a center are placed as shown in figure 8-1 (A). The bottom of the buckets is sealed by contact with what might be called a continuous bottom in the shape of the bounding wall against which they rotate. As the buckets rotate, centrifugal force pushes the liquid against this continuous bottom.

If the buckets are shaped like pieces of pie, and they completely fill the circle, as shown in figure 8-1 (B), then the buckets will act as a paddle wheel revolving in a drum-shaped container. The result is a continuous liquid pressure due to centrifugal force over all the circumference of the container. The pressure is the result of the restriction to the flow of the liquid caused by the walls of the container.

By enlarging the diameter of the container (fig. 8-1 (C)), a space (A) is created for liquid between the ends of the paddles and the drum. The rotation of the liquid in the buckets, because of centrifugal force, pushes outward against the liquid bottom and thereby imparts a pressure to the liquid in space (A). If the liquid remains stationary—which would not actually be the case in practice—then it would be subjected to a true static pressure, the magnitude of which would be dependent upon the centrifugal force of the liquid between the paddles.

If an opening were provided in the containing drum, the centrifugal force would cause the liquid in space (A) to be discharged. If the liquid in space (A) were stationary, this discharge could take any direction because, according to Pascal's law, static pressure in a fluid is transmitted equally in all directions. In practice, however, another factor must be considered which determines the direction of discharge. This factor is explained shortly.

If a means for continuously filling the bucket is provided, such as a central opening in the container, and a source of power to rotate the paddles is provided, then a continuous flow, as shown in figure 8-1 (D), exists. This demonstrates one of the principles that apply to the operation of the centrifugal pump.

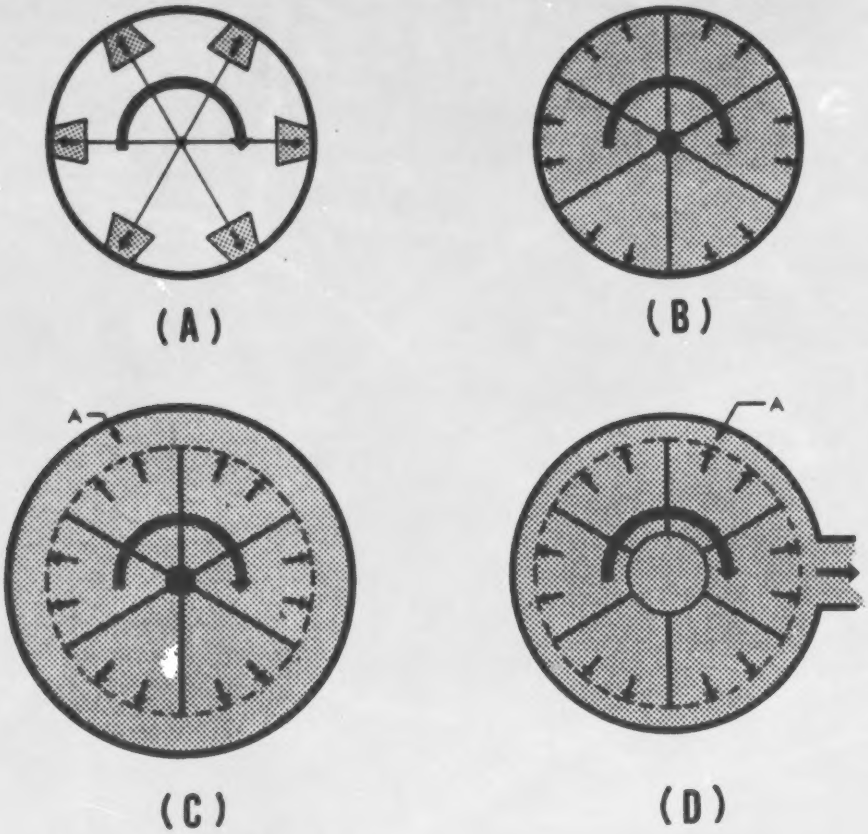

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Figure 8-1.—Centrifugal force.

When a force which is compelling an object to move in a curved path is removed, the object will travel in a straight line with the speed and direction it had at the instant the force was removed. This is illustrated in figure 8-2. An object is attached to a line (R) and swung around in a circular path. Assume that the line breaks when it reaches the vertical position shown. The object will then fly off horizontally (at right angles to the line) with the velocity it had at that moment. This horizontal path will be tangent to the circular path the object was following up to this moment, so this action is commonly called "going off on a tangent," while the velocity is called tangential velocity.

This is the principle of the old fashioned sling shot, in which a man placed a stone in a leather holder to which two strings were attached, swung it around in a circular path several times to impart velocity, and then let go one of the strings. This principle is utilized in the centrifugal pump in addition to the outward action of centrifugal force previously described.

Referring to figure 8-1 (D), as soon as some of the liquid in space (A) is permitted to escape, a continuous suction or low-pressure area will be set up in the center opening. (This center opening is commonly referred to as the eye.) Atmospheric pressure and, in some cases, gravity force acting on the liquid in the reservoir will force liquid into the eye of the container. The blades or paddles will then start rotating the liquid. As the liquid from space (A) flows out of the container, the liquid between the blades will move out to a greater and greater radius. In so doing it will acquire an increasing tangential velocity, because the angular velocity of the blades is constant, and

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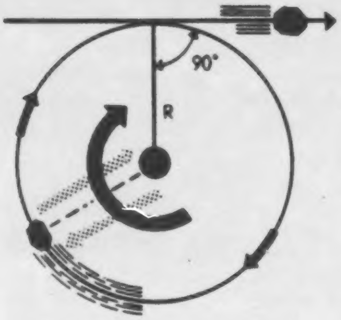


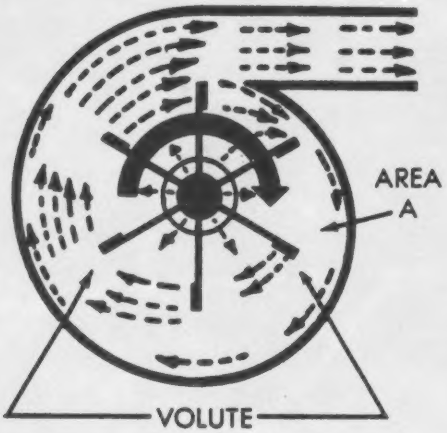
FP.107
Figure 8-2.—Tangential velocity.

as the radius of the circular path increases, the liquid must travel a greater distance per revolution. Eventually, it will reach the tip of the blades and enter space (A), which is equivalent to "going off on a tangent" as described previously. The liquid will also tend to continue moving directly outward from the center of the circle because of its inertia. The two actions—centrifugal and tangential—are then combined.

This liquid that is thrown off the tips of the blades has a velocity equal to the tangential velocity it had the instant it left them. The two actions—centrifugal force and tangential velocity—cause the liquid to flow out of the discharge port.

Since it is part of the meaning of velocity that it have direction (see chapter 2), the direction in which the discharge takes place becomes important. In order to make the most use of the velocity, the discharge is generally in an approximately tangential direction.

The liquid is thrown off the paddles, or impeller blades, as they are called in the pump, all around the circle. Therefore, liquid is added to the space (A) at all points, but escapes from this space at only one point. In order to compensate for this, it is customary to increase the area of space (A) as the outlet is approached. By this means it is also possible to slow down the tangential velocity at a more gradual rate, and thereby obtain more efficient conversion of the velocity in the pump into flow to the system. Therefore, it is customary to design space (A) in the shape like that shown in figure 8-3. This shape—called a volute—continuously expands in a definite ratio.



FP.108
Figure 8-3.—Basic elements of a centrifugal pump.

The details of the size and shape of the volute used are very important to the efficiency of the pump, as are likewise the exact shape, size, and speed of rotation of the impeller. In general, it is true that impeller blades that curve backward with respect to their direction of rotation give better results than straight blades, but the reasons for this and for the other details of construction are matters which concern the designer primarily, and are outside the scope of this training manual.

Types

The two most common types of centrifugal pumps used in hydraulic systems are the volute and diffuser types. In both types, flow is provided by the action of centrifugal force. At the same time, the rotation of the impeller produces the greater part of the velocity that forces the liquid out through the discharge. The major differences between the two types are described in the following paragraphs.

VOLUTE TYPE.—Figure 8-4 illustrates the operation of a volute type centrifugal pump. The impeller discharges the liquid at a high velocity into a progressively expanding casing. This contour of the casing directs the movement of the liquid through the outlet port and into the system.

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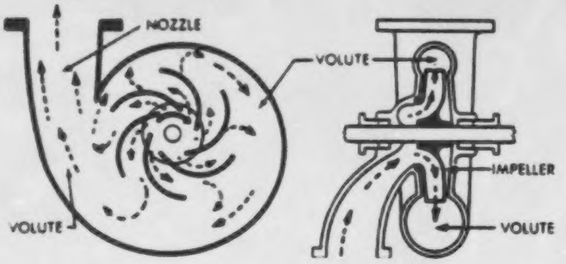
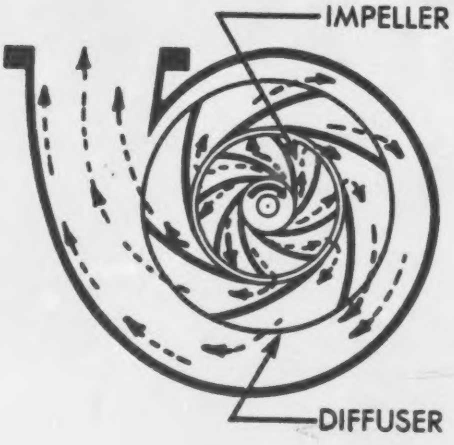


FP.109

Figure 8-4.—Volute type centrifugal pump.

DIFFUSER TYPE.—Figure 8-5 illustrates the diffuser type pump. It is similar in design to the volute pump, with the addition of a series of stationary blades incorporated around the outside circumference of the impeller blades. These stationary blades are termed the diffuser. The diffuser blades are curved in the opposite direction from the rotating impeller blades. The diffuser reduces the velocity of the liquid and decreases slippage (previously described), which increases the efficiency of the pump.



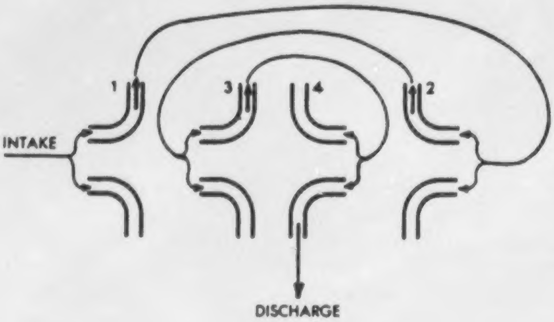
FP.110

Figure 8-5.—Diffuser type centrifugal pump.

Classification

Centrifugal pumps are classified in several ways. For example, they may be either single-stage or multistage. A single-stage pump has only one impeller. A multistage pump has two or more impellers housed together in one casing. As a rule, each impeller acts separately, discharging to the inlet (suction) side of the next stage impeller. For the sake of compactness, the several impellers which make up a multistage pump are almost invariably placed on one shaft. Figure 8-6 shows a possible flow diagram for a four-stage pump.

The illustrations of centrifugal pumps in this section emphasize horizontal pumps; that is, pumps with their shaft parallel to the horizontal axis. These pumps can operate just as efficiently when installed in such a position that the shaft is parallel to the vertical axis. However, these pumps are sometimes classified as horizontal or vertical pumps.



FP.111

Figure 8-6.—Flow diagram of a four-stage centrifugal pump.

The impellers used in centrifugal pumps may be classified as single-suction or double-suction. The single-suction impeller allows liquid to enter the eye from one direction only; the double-suction type allows liquid to enter the eye from two directions. Impellers are also classified as CLOSED or OPEN. Closed impellers have side walls that extend from the eye to the outer edge of the blade tips; open impellers do not have these side walls.

Manufacturers sometimes classify centrifugal pumps according to the size and shape of the casing, arrangement of the discharge nozzle in relation to the pumping chamber, and the type of material used in construction of the pump.

Centrifugal pumps may be driven by any of the sources mentioned previously in this chapter. Many of the centrifugal pumps aboard ship are driven by steam turbines. As a rule, centrifugal pumps are direct drive—that is, the impeller rotates at the same rpm as the power source.

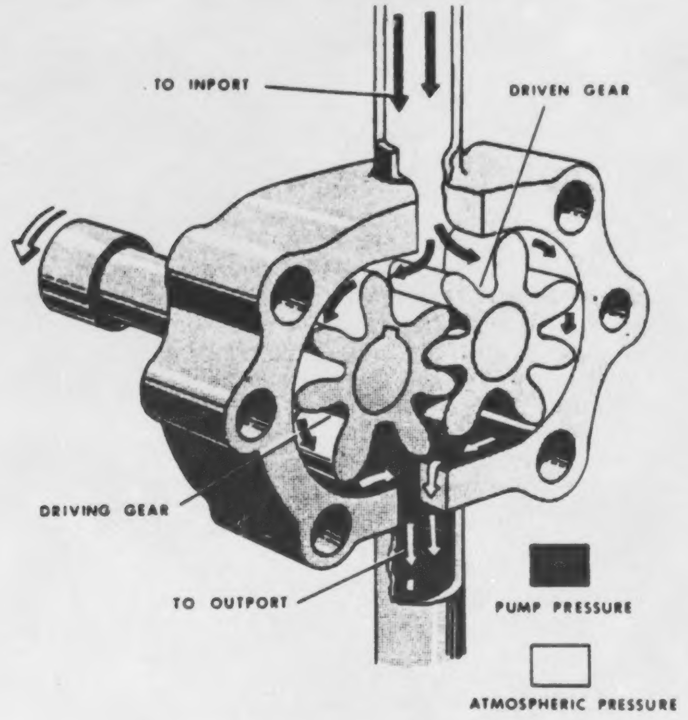


Figure 8-7.—Gear type rotary pump.

However, some low-pressure centrifugal pumps have reduction gears installed between the power source and the impeller. This allows the power source to operate at a high speed and the impeller to operate at a lower speed, thus obtaining maximum efficiency from both the power source and the pump.

Applications

Since centrifugal pumps are nonpositive displacement, their use in hydraulic systems is normally limited to systems that require a large volume of flow and operate at a relatively low pressure. Some hydraulic systems require variations of flow and pressure. A centrifugal pump is sometimes used in combination with a positive displacement pump to supply the demands of such systems. The positive displacement pump maintains the system during periods requiring low volume and high pressure. The centrifugal pump aids the positive displacement pump when the system requires large volumes and low pressure.

In some hydraulic systems a centrifugal pump is used with a variable displacement pump. Both pumps are driven by the same electric motor. The motor is fully enclosed and is cooled by a flow of liquid from the centrifugal pump. The centrifugal pump also provides a supply of liquid to the inlet port of the variable displacement pump. This insures an adequate supply of liquid to the main pump (variable displacement) for all demands of the system.

ROTARY PUMPS

All rotary pumps operate by means of rotating parts which trap the fluid at the inlet (suction) port and force it through the discharge port into the system. Gears, screws, lobes, and vanes are commonly used as elements in rotary pumps. Rotary pumps operate on the positive displacement principle and are of the fixed displacement type.

Rotary pumps are designed with very small clearances between rotating parts and between rotating parts and stationary parts, in order to minimize slippage from the discharge side back to the suction side. Pumps of this type are designed to operate at relatively moderate speeds in order to maintain these clearances. Operation at higher speed causes erosion and excessive wear, resulting in increased clearances.

Classification

Like centrifugal pumps, there are numerous types of rotary pumps and various methods of classification. They may be classified as to shaft position—either vertically or horizontally mounted; the type of drive—electric motor, gasoline engine, etc.; manufacturer's name; or service application. However, classification of rotary pumps is generally made according to the type of rotating element. A few of the most common types of rotary pumps are discussed in the following paragraphs.

GEAR.—The simple gear pump (fig. 8-7) consists of two meshed gears which revolve in a housing. The drive gear in the illustration in turned by a drive shaft which engages the power source. The clearances between the gear teeth as they mesh and between the teeth and the pump housing are very small.

The inlet port is connected to the fluid supply line, and the outlet port is connected to the pressure line. Referring to figure 8-7, the drive gear is turning in a counterclockwise direction, and the driven (idle) gear is turning in a clockwise direction. As the teeth pass the inlet port, liquid is trapped between the teeth and the housing. This liquid is carried around the housing to the outlet port. As the teeth mesh again, the liquid between the teeth is displaced into the outlet port. This action produces a positive flow of liquid into the system. A shearpin or shear section is incorporated in the drive shaft. This is to protect the power source or reduction gears if the pump fails because of excessive load or jamming of parts.

The gears of the pump illustrated in figure 8-7 are referred to as spur gears. Herringbone and helical gears are also used in the construction of gear pumps.

The herringbone gear pump (fig. 8-8) is a modification of the simple gear pump. The liquid is pumped in the same manner as in the spur gear pump. However, in the operation of the herringbone pump, one discharge phase begins before the previous discharge phase is entirely complete. This overlapping and the relatively larger space at the center of the gears tend to minimize pulsations and give a steadier flow than is produced by the spur gear pump.

The helical gear pump is still another modification of the simple gear pump. Because of the helical gear design, the overlapping of successive discharges from spaces between the teeth is even greater than it is in the herringbone gear pump; therefore, the discharge flow is smoother. Since the discharge flow is smooth in the helical pump, the gears can be designed with a small number of large teeth—thus allowing increased capacity without sacrificing smoothness of flow.

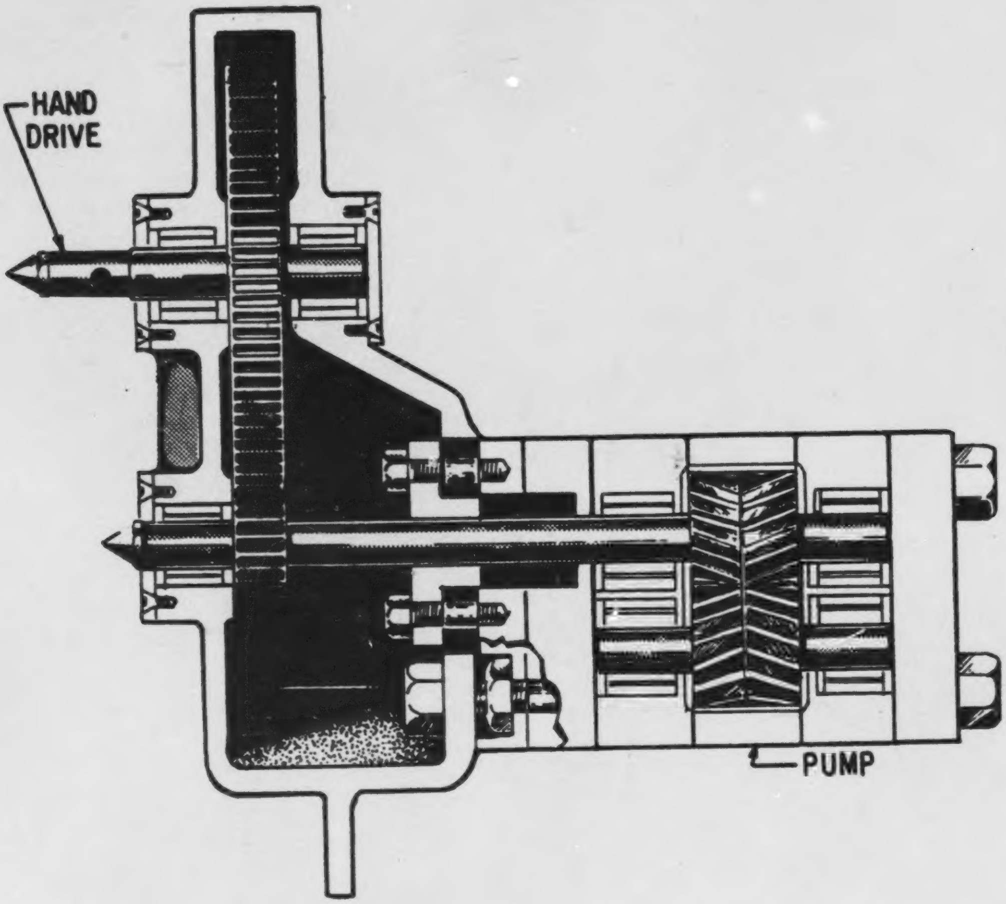
Figure 8-9 shows a helical gear pump. The pumping gears of this type pump are driven by a set of timing and driving gears, which also function to maintain the required close clearances while preventing actual metallic contact between the pumping gears. (Metallic contact between the teeth of the pumping gears would provide a tighter seal against slippage; however, it would cause rapid wear of the teeth, because foreign matter in the liquid would be present on the contact surfaces.)

Roller bearings at both ends of the gear shafts maintain proper alignment and minimize the friction loss in the transmission of power. Suitable packings are used to prevent leakage around the shaft.

The spur, herringbone, and helical are all classified as external gear pumps. This is because both sets of teeth project outward from the center of the gears. In an internal gear pump, the teeth of one gear project outward, but the teeth of the other gear project inward toward the center of the pump, as shown in figure 8-10 (A). One gear wheel—the external gear—stands inside the other—the internal gear.

One type of internal gear pump is illustrated in figure 8-10 (B). The external (drive) gear is attached directly to the drive shaft of the pump and is placed offcenter in relation to the internal gear. The two gears mesh on one side of the pump, between the inlet (suction) and discharge ports. On the opposite side of the chamber, a crescent-shaped form is located in the space between the two gears in such a way as to provide a close tolerance with them.

The rotation of the center gear by the drive shaft causes the outside gear to rotate, since the two are in mesh. Everything in the chamber rotates except the crescent. This action causes liquid to be trapped in the gear spaces as they



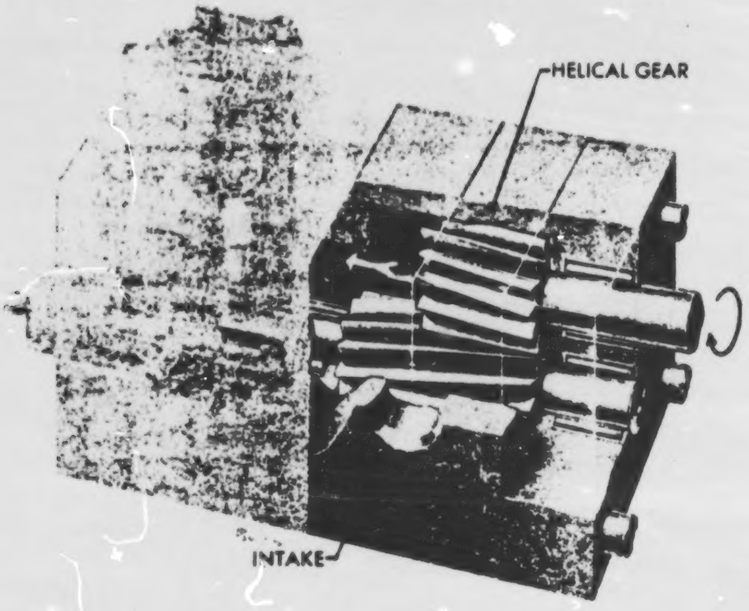
FP.113

Figure 8-8.—Herringbone gear pump.

the crescent. The liquid is carried from the inlet port to the discharge port, where it is forced out of the pump by the meshing of the gears. As the liquid is forced from the inlet side of the pump, a low-pressure area is created at the inlet port allowing atmospheric pressure to force liquid into the pump from the source of supply. The size of the crescent that separates the internal and external gears is the determining factor in the volume delivery of the pump. A small crescent allows more volume of liquid per revolution than a larger crescent.

Another design of internal gear pump is illustrated in figures 8-11 and 8-12. This pump consists of a pair of gear-shaped elements, one within the other, located in the pump chamber. The inner gear is connected to the drive shaft of the source of power.

The operation of this type internal gear pump is illustrated in figure 8-12. To simplify the explanation, the teeth of the inner gear and the spaces between the teeth of the outer gear are numbered. Note that the inner gear has one less tooth than the outer gear. The tooth form of each gear is related to that of the other in such a way that each tooth of the inner gear is always in sliding contact with the surface of the outer gear. Each tooth of the inner gear meshes with the outer gear at just one point during each revolution. In the illustration, this point is at the top (X). In view A, tooth 1 of the inner gear is in mesh with space 1 of the outer

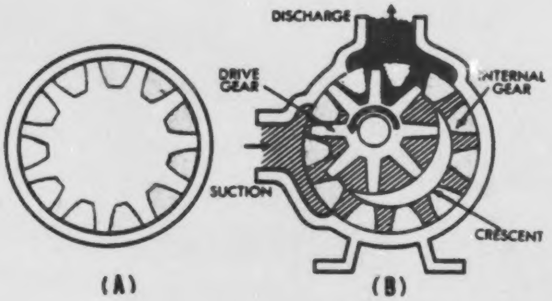

HELICAL GEAR
INTAKE

FP.114

Figure 8-9.—Helical gear pump.

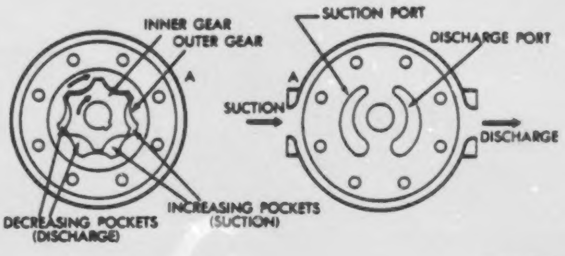
gear. As the gears continue to rotate in a clockwise direction and the teeth approach point (X), tooth 6 of the inner gear will mesh with space 7 of the outer gear, tooth 5 with space 6, etc. During this revolution, tooth 1 will mesh with space 2; and the following revolution, tooth 1 will mesh with space 3. As a result, the outer gear will rotate at just six-sevenths the speed of the inner gear. For example, if the inner gear rotates at 1,400 rpm, the outer gear will rotate at 1,200 rpm.

At one side of the point of mesh, pockets of increasing size are formed as the gears rotate, while on the other side the pockets decrease in size. In figure 8-12, the pockets on the right-hand side of the drawings are increasing in size as one moves down the illustration, while those on the left-hand side are decreasing in size. The intake side of the pump would therefore be to the right and the discharge to the left. In figure 8-11, since the right-hand side of the drawing was turned over to show the ports, the intake and discharge appear reversed. Actually, A in one drawing covers A in the other.


DISCHARGE
DRIVE GEAR
INTERNAL GEAR
SUCTION
CRESCENT
(A)
(B)

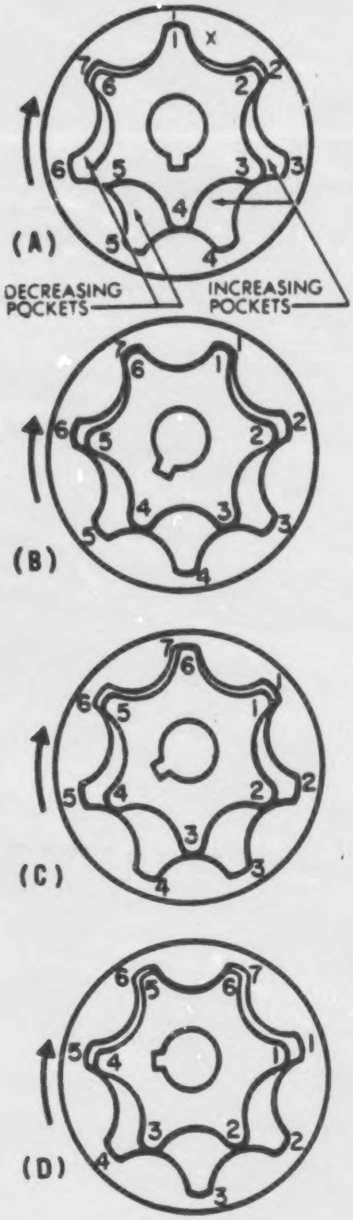
FP.115

Figure 8-10.—Offcentered internal gear pump.


INNER GEAR
OUTER GEAR
A
SUCTION PORT
DISCHARGE PORT
A
SUCTION
DISCHARGE
DECREASING POCKETS (DISCHARGE)
INCREASING POCKETS (SUCTION)

FP.116

Figure 8-11.—Centered internal gear pump.

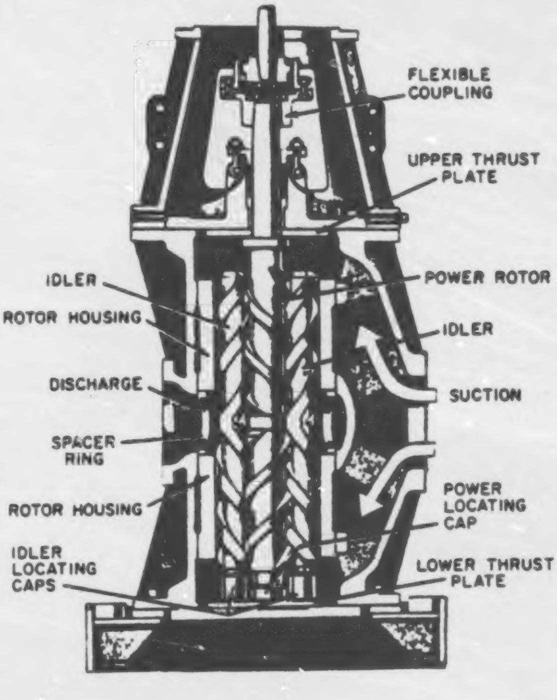

x
(A)
DECREASING POCKETS
INCREASING POCKETS
(B)
(C)
(D)

FP.117

Figure 8-12.—Principles of operation of the internal gear pump.

SCREW.—Another type of rotating element used in rotary pumps is the screw. The design of this element is similar to that of a worm gear and, therefore, is sometimes classified as a gear type pump. The screw pump has two or more meshing screws which rotate to develop fluid flow. These screws mesh to form a fluid-tight seal between the screws and between the screws and the housing.

Screw type pumps are available in several different designs; however, they all operate in a similar manner. One design of a screw pump is illustrated in figure 8-13. Since this pump contains three screws, it is referred to as a triple screw pump. The screws revolve within a close-fitting housing. The power screw (rotor) in the center is in mesh with (and drives) the two idling rotors (idlers).


FLEXIBLE COUPLING
UPPER THRUST PLATE
IDLER
POWER ROTOR
ROTOR HOUSING
IDLER
DISCHARGE
SUCTION
SPACER RING
POWER LOCATING CAP
ROTOR HOUSING
IDLER LOCATING CAPS
LOWER THRUST PLATE

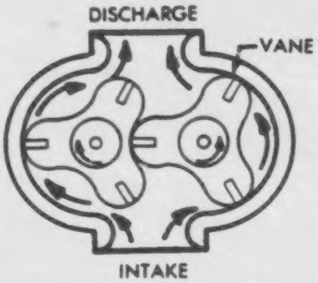
FP.118

Figure 8-13.—Triple screw pump.

The supply line is connected to the pump intake which, in turn, opens into the chambers at the ends of the screw assembly. As the screws turn, the liquid flows in between the threads at each end of the assembly. At the end of the first turn, a spiral-shaped quantity of fluid is trapped when the ends of the threads become in mesh again. The threads carry the fluid along within the housing toward the center of the pump to the discharge port.

In some screw pumps, the intake port is located near one end of the pump and the discharge near the other. In these pumps the screws are designed in such a manner that fluid enters one end of the pump, is forced through the pump by the screws to the opposite end, and is discharged into the system.

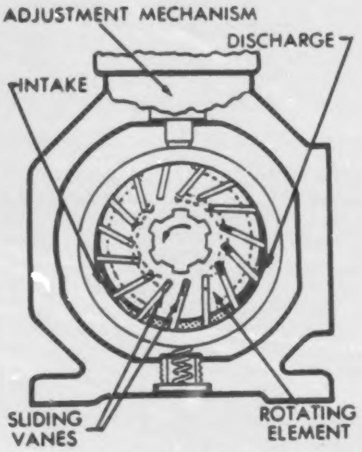
LOBE.—The principle of operation of the lobe pump is exactly the same as for the external gear pump described previously. The lobes are considerably larger than gear teeth, but there are only two or three lobes on each rotor. A three-lobe pump is illustrated in figure 8-14. The two elements are rotated, one being directly driven by the source of power, and the other through timing gears. As the elements rotate, liquid is trapped between two lobes of each rotor and the walls of the pump chamber, and carried around from the intake side to the discharge side of the pump. As liquid leaves the intake chamber, the pressure in the intake chamber is lowered, and additional liquid is forced into the chamber from the source of supply.



FP.119

Figure 8-14.—Lobe pump.

The lobes are so constructed that there is a continuous seal at the point of juncture at the center of the pump. The lobes of the pump illustrated in figure 8-14 are fitted with small vanes, at the outer edge to improve the seal of the pump. Although these vanes are mechanically held in their slots, they are, to some extent, free to move outward. Centrifugal force keeps the vanes snug against the chamber and the other rotating members.



FP.120

Figure 8-15.—Vane pump

VANE.—Figure 8-15 illustrates a vane pump of the unbalanced design. The rotor is attached to the drive shaft and is rotated by an outside power source such as an electric motor, gasoline engine, etc. The rotor is slotted and each slot is fitted with a rectangular vane. These vanes, to some extent, are free to move outward in their respective slots. The rotor and vanes are enclosed in a housing, the inner surface of which is offset with the drive axis.

As the rotor turns, centrifugal force keeps the vanes snug against the wall of the housing. The vanes divide the area between the rotor and housing into a series of chambers. The chambers vary in size according to their respective positions around the shaft. The inlet port is located in that part of the pump where the chambers are expanding in size so that the partial vacuum formed by this expansion allows liquid to flow into the pump. The liquid is trapped between the vanes and is carried to the outlet side of the pump. The chambers contract in size on the outlet side, and this action forces the liquid through the outlet port and into the system.

The pump in figure 8-15 is referred to as unbalanced because all of the pumping action takes place on one side of the shaft and rotor. This causes a side load on the shaft and rotor. Some vane pumps are constructed with an eliptical-shaped housing which forms two separate pumping areas on opposite sides of the rotor. This cancels out the side loads; therefore, such pumps are referred to as balanced vane.

Application

Although some rotary pumps are capable of operating in high-pressure systems (above 1,500 psi), their use is usually limited to systems which operate at pressures of 1,500 psi or below. As compared to other types of hydraulic pumps, rotary pumps are less expensive, have fewer moving parts, and feature simplicity in designs and construction.

The efficiency of rotary pumps depends on the close tolerances between the rotating elements and, in most pumps, between the rotating element and the housing of the pump. This efficiency is quickly reduced by excessive wear. For this reason, dirt picked up by the liquid must be eliminated by suitable filters.

Rotary pumps are usually used in hydraulic systems that do not require the continuous, or near continuous, operation of the pump. For example, electric-motor-driven gear pumps are often used to operate the emergency hydraulic systems in aircraft. This provides an efficient pump to supply fluid to the system in case of main system failure. It is far less expensive than the type pump generally used in the main system and, due to its limited use, maintains efficiency.

RECIPROCATING PUMPS

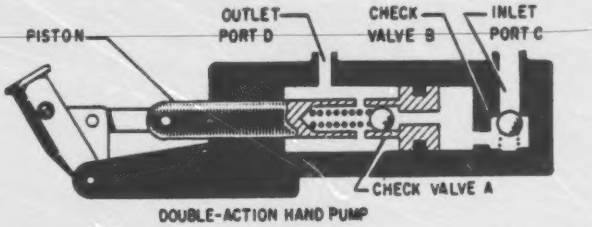
The term reciprocating is defined as back-and-forth motion. In the reciprocating pump it is this back-and-forth motion of pistons inside of cylinders which provides the flow of fluid. Reciprocating pumps, like rotary pumps, operate on the positive principle—that is, each stroke delivers a definite volume of liquid to the system.

The master cylinder of the automobile brake system, which is described and illustrated in chapter 4, is an example of a simple reciprocating pump. Most manually operated hydraulic pumps are of the reciprocating type. Several types of power operated hydraulic pumps, such as the radial piston and axial piston, are also classified as reciprocating pumps. These pumps are sometimes classified as rotary pumps, because a rotary motion is imparted to the pumps by the source of power. However, the actual pumping is performed by sets of pistons reciprocating inside sets of cylinders. Some of these different types of reciprocating pumps are discussed in the following paragraphs.

Hand Pumps

There are two types of manually operated reciprocating pumps—the single-action and the double-action. The single-action pump provides flow during every other stroke, while the double-action provides flow during each stroke. Single-action pumps are frequently used in hydraulic jacks. This type pump is illustrated in figure 4-6 in chapter 4.

A double-action hand pump is illustrated in figure 8-16. This type pump is used in some aircraft hydraulic systems as a source of hydraulic power for emergencies, for testing certain subsystems during preventive maintenance inspections, and for determining the causes of malfunctions in these subsystems. This type pump is also used as a secondary source of hydraulic power in hydraulic test benches to test hydraulic components.



FP.121

Figure 8-16.—Hydraulic hand pump.

This pump consists of a cylinder, a piston containing a built-in check valve (A), a piston rod, an operating handle, and a check valve (B) at the inlet port. When the piston is moved to the left, the force of the liquid in the outlet chamber and spring tension cause valve (A) to close. This movement causes the piston to force the liquid in the outlet chamber through the outlet port (D) and into the system. This same movement of the piston causes a low-pressure area in the inlet chamber. Atmospheric pressure acting on the liquid in the reservoir transmits this pressure to the liquid at the inlet port (C). This differential of pressures acting on the ball of check valve (B) causes the spring to compress and open the check valve. This allows liquid to enter the inlet chamber.

When the piston completes this stroke to the left, the inlet chamber is full of liquid. This liquid eliminates the low-pressure area in the inlet chamber, thereby allowing spring tension to close check valve (B).

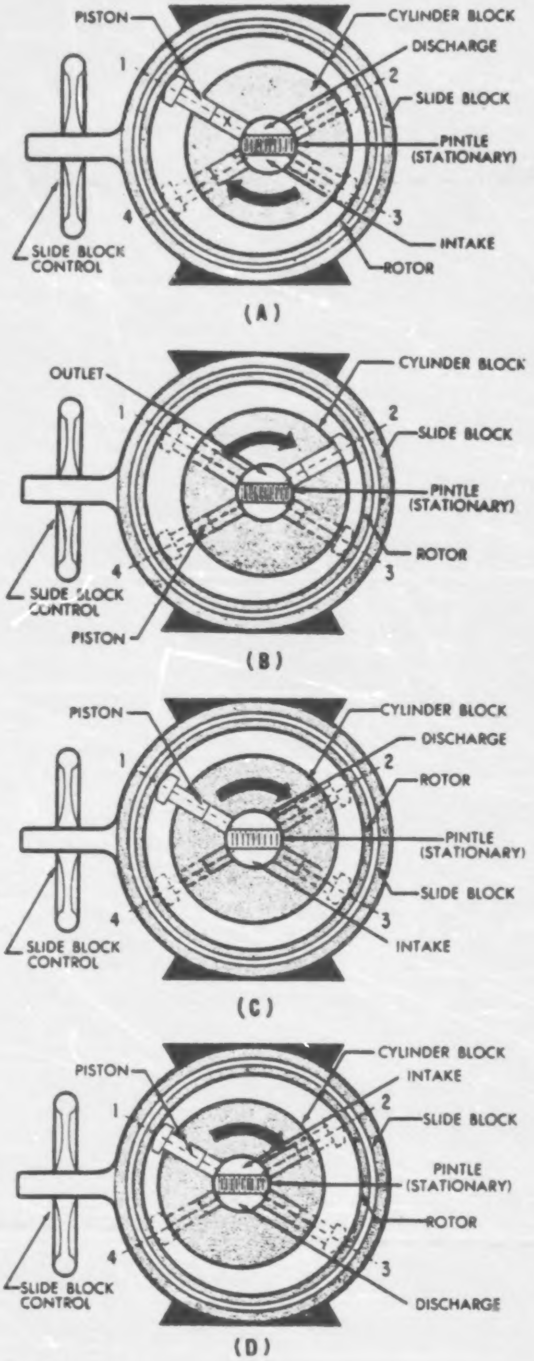
When the piston is moved to the right, the force of the confined liquid in the inlet chamber acts on the ball of check valve (A). This action compresses the spring and opens check valve (A), allowing the liquid to flow from the intake chamber to the outlet chamber. Because of the area occupied by the piston rod, the outlet chamber cannot contain all the liquid discharged from the inlet chamber. Since the liquid will not compress, the extra liquid is forced out of port (D) into the system.

Radial Piston Pumps

Figure 8-17 illustrates the operation of the radial piston pump. The pump consists of a pintle which remains stationary and acts as a valve; a cylinder block which revolves around the pintle and contains the cylinders in which the pistons operate; a rotor which houses the reaction ring of hardened steel against which the piston heads press; and a slide block which is used to control the length of the piston strokes. The slide block does not revolve but houses and supports the rotor, which does revolve due to the friction set up by the sliding action between the piston heads and the reaction ring. The cylinder block is attached to the drive shaft.

Referring to view (A) of figure 8-17, assume that space (X) in one of the cylinders of the cylinder block contains liquid and that the respective piston of this cylinder is at position (1). When the cylinder block and piston are rotated in a clockwise direction, the piston is forced into its cylinder as it approaches position (2). This action reduces the volumetric size of the cylinder and forces a quantity of liquid out of the cylinder and into the outlet port above the pintle. This pumping action is due to the fact that the rotor, in the slide block, is off centered in relation to the center of the cylinder block.

In figure 8-17 (B), the piston has reached position (2) and has forced the liquid out of the open end of the cylinder through the outlet above the pintle and into the system. While the piston moves from position (2) to position (3), the open end of the cylinder passes over the solid part of the pintle; therefore, there is no intake or discharge of liquid during this time. As the


PISTON
CYLINDER BLOCK
DISCHARGE
1
2
X
SLIDE BLOCK
PINTLE (STATIONARY)
4
3
INTAKE
SLIDE BLOCK CONTROL
ROTOR
(A)
OUTLET
CYLINDER BLOCK
1
2
SLIDE BLOCK
PINTLE (STATIONARY)
ROTOR
4
3
SLIDE BLOCK CONTROL
PISTON
(B)
PISTON
CYLINDER BLOCK
DISCHARGE
1
2
ROTOR
PINTLE (STATIONARY)
SLIDE BLOCK
4
3
SLIDE BLOCK CONTROL
INTAKE
(C)
CYLINDER BLOCK
PISTON
INTAKE
1
2
SLIDE BLOCK
PINTLE (STATIONARY)
ROTOR
4
3
SLIDE BLOCK CONTROL
DISCHARGE
(D)

FP.122

Figure 8-17.—Principles of operation of the radial piston pump.

piston and cylinder move from position (3) to position (4), centrifugal force causes the piston to move outward against the reaction ring of the rotor. During this time the open end of the cylinder is open to the intake side of the pintle and, therefore, fills with liquid. As the piston moves from position (4) to position (1), the open end of the cylinder is against the solid side of the pintle and no intake or discharge of liquid takes place. After the piston has passed the pintle and starts toward position (2), another discharge of liquid takes place. Alternate intake and discharge continues as the rotor is revolved about its axis—intake on one side of the pintle and discharge on the other, as the piston slides in and out.

Notice in views (A) and (B) of figure 8-17 that the center point of the rotor is different from the center point of the cylinder block. It is the difference of these centers that produces the pumping action. If the rotor is moved so that its center point is the same as that of the cylinder block, as shown in figure 8-17 (C), there is no pumping action, since the piston does not move back and forth in the cylinder as it rotates with the cylinder block.

The flow in this pump can be reversed by moving the slide block, and therefore the rotor, to the right so that the relation of the centers of the rotor and the cylinder block is reversed from the position shown in views (A) and (B) of figure 8-17. Figure 8-17 (D) shows this arrangement. Liquid enters the cylinder as the piston travels from position (1) to position (2) and is discharged from the cylinder as the piston travels from position (3) to (4).

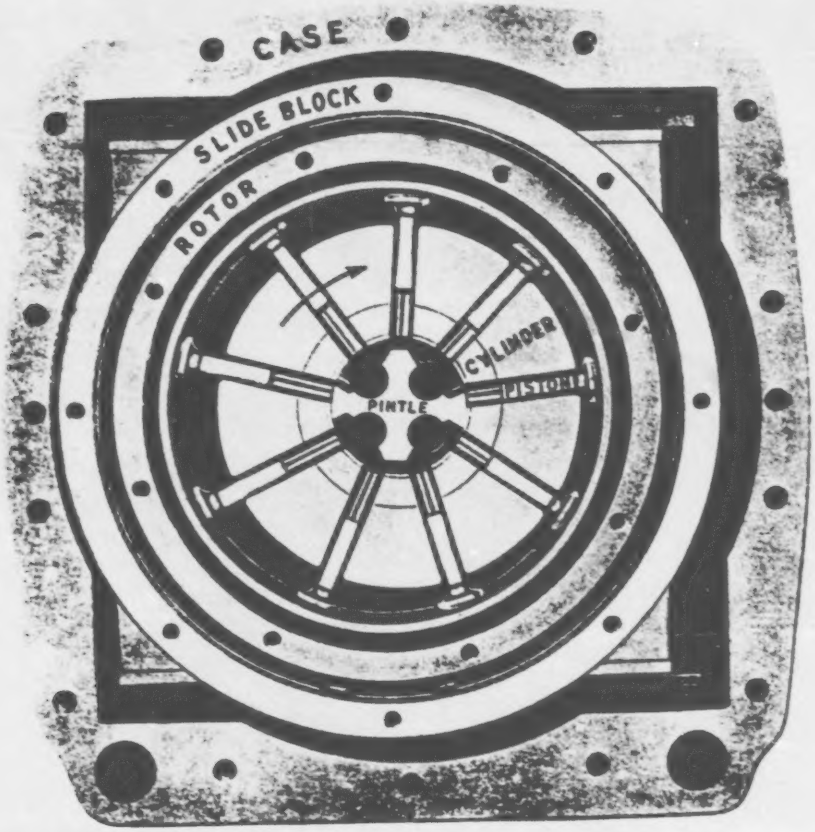
In the illustrations the rotor is shown in the center, the extreme right, or the extreme left in relation to the cylinder block. The amount of adjustment in distance between the two centers determines the length of the piston stroke, which controls the amount of liquid flow in and out of the cylinder. Thus, this adjustment determines the displacement of the pump; that is, the volume of liquid the pump delivers per revolution. This adjustment may be controlled in different ways. Manual control by means of a handwheel is the simplest. The pump illustrated in figure 8-17 is controlled in this way. For automatic control of delivery to accommodate varying volume requirements during the operating cycle, a hydraulically controlled cylinder may be used to position the slide block. A gear-motor controlled by a pushbutton or limit switch is sometimes used for this purpose.

A pump of this type with only one piston would not be practical. Therefore, the radial piston pump is designed with several pistons. Note that the pump illustrated in figure 8-18 contains an odd number of pistons. All radial pumps are designed with an odd number of pistons—7, 9, 11, etc. This is to insure that no more than one cylinder is completely blocked by the pintle at any one time. If there were an even number of pistons spaced evenly around the cylinder block (for example, eight), there would be occasions when two of the cylinders would be blocked by the pintle, while at other times none would be blocked. This would cause three cylinders to discharge at one time and four at one time, causing pulsations in flow. With an odd number of pistons spaced evenly around the cylinder block, only one cylinder is completely blocked by the pintle at any one time. This reduces pulsations of flow.

Some of the principal parts of the radial piston pump are described in more detail in the following paragraphs.

PINTLE.—In figure 8-17 the pintle is shown, for the sake of simplicity, as a flat bar around which the rotor turns. Actually, the pintle is a round bar which serves as a stationary shaft around which the cylinder block turns. The pintle shaft, as shown in figure 8-19, has four holes bored from one end lengthwise through part of its length. Two holes serve as the intake and the remaining two as the discharge. Two slots are cut in the side of the shaft so that each slot connects two of the lengthwise holes. The two slots are in line with the cylinders when the cylinder block is assembled on the pintle. One of these slots provides the path for the liquid to pass from the cylinders to the discharge hole bores into the pintle. The other slot connects the two inlet holes to the cylinders during the entrance of liquid. The discharge holes are connected through appropriate fittings to a discharge line so that the liquid can be directed into the system. The other pair of holes are connected to the inlet line.

CYLINDER BLOCK.—One type of cylinder block is illustrated in figure 8-20. This is a cylindrical-shaped block of metal with a hole bored through the center to accommodate the pintle. The cylinder holes are bored from the outer edge of the block to the center hole and are spaced at equal distances around the circumference of the block. Both the cylinder holes and the center hole are very accurately machined so that liquid loss around the pistons and the



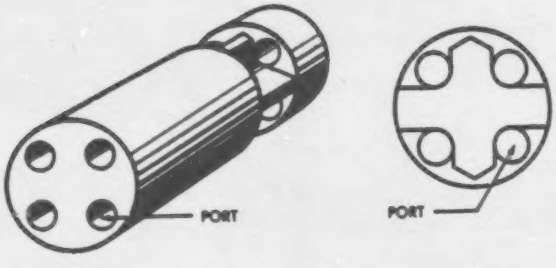
FP.123

Figure 8-18.—Nine-piston radial piston pump.

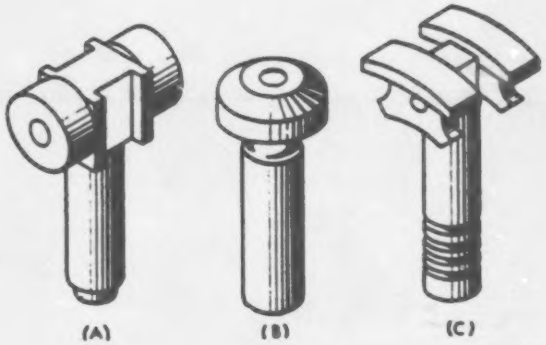
pintle is kept to a minimum. There are several different designs of cylinder blocks. Some, like the one illustrated in figure 8-20, appear to be almost solid, while others have spokelike cylinders radiating out from the center.

PISTONS.—Like cylinder blocks, pistons are manufactured in different designs. Some of these designs are illustrated in figure 8-21. View (A) shows a piston with small wheels that roll around the inside surface of the rotor. View (B) shows a piston in which the conical edge of the top bears directly against the reaction ring of the rotor. In this particular design, while the piston moves back and forth in the cylinder, it will rotate about its axis, so that the top surface will wear uniformly. View (C) shows a piston attached to curved plates. These curved plates, sometimes referred to as curved shoes or slippers, bear against and slide around the inside surface of the rotor. Like the cylinder walls, the sides of the pistons are accurately machined to fit the cylinders, so there is a minimum loss of liquid between the walls of the cylinders and the pistons. No provision is made for the use of piston rings to help seal against leakage.

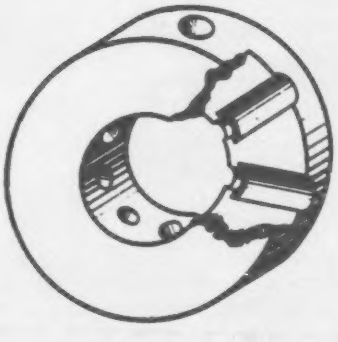
ROTOR.—Here again, the design may be different from pump to pump, as shown in figure 8-22. The rotor consists essentially of a circular ring, machine finished on the inside, against which the pistons bear. The rotor rotates within the slide block which can be shifted from side to side to control the length of the stroke of the



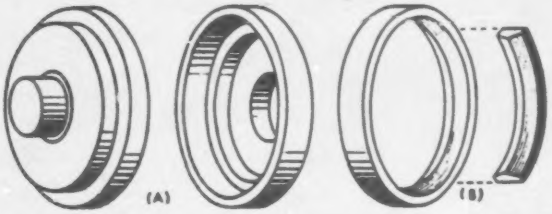
FP.124
Figure 8-19.—Pintle for radial piston pump.



FP.126
Figure 8-21.—Pistons for radial piston pump.



FP.125
Figure 8-20.—Cylinder block for radial piston pump.



FP.127
Figure 8-22.—Rotors for radial piston pump.

pistons. The slide block has two pairs of machined surfaces on the exterior so that it can slide in tracks in the pump case. The sliding motion is controlled by any means covered earlier in this chapter.

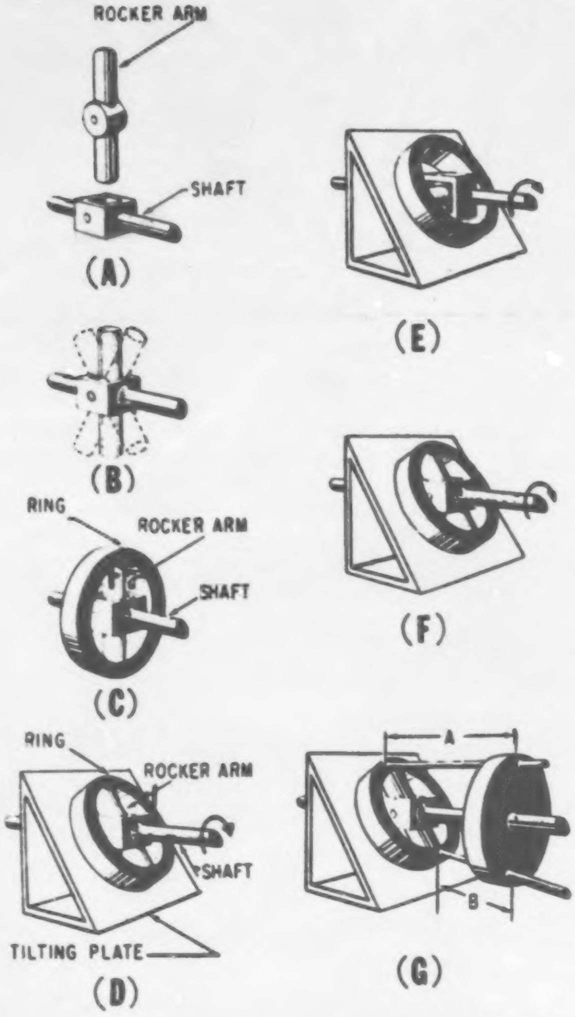
These parts, together with the drive shaft, constitute the main working parts of the radial piston pump. The drive shaft is connected to the cylinder block and is driven by an outside force such as an electric motor.

Axial Piston Pumps

Axial piston pumps have the same general characteristics as radial piston pumps. However, in the axial piston pump, the block with its pistons rotate on a shaft in such a way that the pistons reciprocate in their cylinders along lines parallel to the axis of the shaft. This is called axial motion.

The pumping action of this pump is made possible by a universal joint or link. Figure 8-23 is a series of drawings which illustrates how the universal joint is used in the operation of the axial piston pump.

First, a rocker arm is installed on a horizontal shaft. (See fig. 8-23 (A).) The arm is joined to the shaft by a pin in such a way that it can be swung back and forth, as indicated in view (B). Next, a ring is placed around the shaft and secured to the rocker arm so that the ring can turn from left to right as shown in view (C). This provides two rotary motions in different planes at the same time, and in varying proportions as may be desired. The rocker arm can swing back and forth in one arc, and the ring can simultaneously move from left to right in



FP.128

Figure 8-23.—Relationship of the universal joint in operation of the axial piston pump.

another arc, in a plane at right angles to the plane in which the rocker arm turns.

Next, a tilting plate is added to the assembly. The tilting plate is placed at a slant to the axis of the shaft, as depicted in figure 8-23 (D). The rocker arm is then slanted at the same angle as the tilting plate, so that it lies parallel to the tilting plate. The ring is also parallel to, and in contact with, the tilting plate. The position of the ring in relation to the rocker arm is unchanged from that shown in figure 8-23 (C).

Figure 8-23 (E) shows the assembly after the shaft, still in a horizontal position, has been rotated a quarter turn. The rocker arm is still in the same position as the tilting plate, and is now perpendicular to the axis of the shaft. The ring has turned on the rocker pins, so that it has changed its position in relation to the rocker arm, but it remains parallel to, and in contact with, the tilting plate.

View (F) of figure 8-23 shows the assembly after the shaft has been rotated another quarter turn. The parts are now in the same position as shown in view (D), but with the ends of the rocker arm reversed. The ring still bears against the tilting plate.

As the shaft continues to rotate, the rocker arm and the ring turn about their pivots, with each changing its relation to the other, and with the ring always bearing on the plate.

Figure 8-23 (G) shows a wheel added to the assembly. The wheel is placed upright and fixed to the shaft, so that it rotates with the shaft. In addition, two rods, (A) and (B), are loosely connected to the tilting ring, and extend through two holes standing opposite each other in the fixed wheel. As the shaft is rotated, the fixed wheel turns perpendicular to the shaft at all times. The tilting ring rotates with the shaft and always remains tilted, since it remains in contact with the tilting plate. Referring to view (G), the distance along rod (A), from the tilting ring to the fixed wheel, is greater than the distance along rod (B). As the assembly is rotated, however, the distance along rod (A) decreases as its point of attachment to the tilting ring moves closer to the fixed wheel, while the distance along rod (B) increases. These changes continue until after a half revolution, at which time the initial positions of the rods have been reversed. After another half revolution, the two rods will again be in their original positions.

As the assembly rotates, the rods are moved in and out through the holes in the fixed wheel. This is the way that the axial piston pump works. To get a pumping action, it is only necessary to place pistons at the ends of the rods, beyond the fixed wheel, and insert them in cylinders. The rods must be connected to the pistons and to the wheel by ball and socket joints. As the assembly rotates, each piston moves back and forth in its cylinder. Intake and discharge lines can be arranged so that liquid enters the cylinders while the spaces between the piston heads and the bases of the cylinders are increasing, and leaves the cylinders during the other half of each revolution when the pistons are moving in the opposite direction.

These operating principles are illustrated in the different views of the axial piston pump shown in figures 8-24 and 8-25. This type pump consists of a circular cylinder with either 7 or 9 equally spaced pistons.

The main parts of the pump are the drive shaft, pistons, cylinder block, and valve plate. There are two ports in the valve plate. These ports connect directly to openings in the face of the cylinder block. Liquid is forced in one port by atmospheric pressure and forced out the other port by the reciprocating action of the pistons.

There is a fill port in the top of the cylinder housing. This opening is normally kept plugged, but it can be opened for testing the pressure in the housing or case. When installing a new pump or a newly repaired one, this plug must be removed and the housing filled with the recommended liquid before the pump is operated. There is a drain port in the mounting flange to drain away any leakage from the drive shaft oil seal.

When the drive shaft is rotated, it rotates the pistons and cylinder block with it. The offset position of the cylinder block causes the pistons to move back and forth in the cylinder block while the shaft, pistons, and cylinder block rotate together. As the pistons reciprocate in the cylinder block, liquid enters one port and is forced out the other.

In figure 8-25, piston (A) is shown at the bottom of the stroke. When piston (A) has rotated to the position held by piston (B) it will have moved upward in its cylinder, forcing liquid through the outlet port during the entire distance. During the remainder of the rotation back to its original position, the piston travels downward in the cylinder. This action creates a low-pressure area in the cylinder; therefore, atmospheric pressure forces liquid through the inlet port into the cylinder. Since each one of the pistons performs the same operation in succession, liquid is constantly being taken into the cylinder bores through the inlet port and discharged from the cylinder bores into the system. This action provides a steady, non-pulsating flow of liquid.

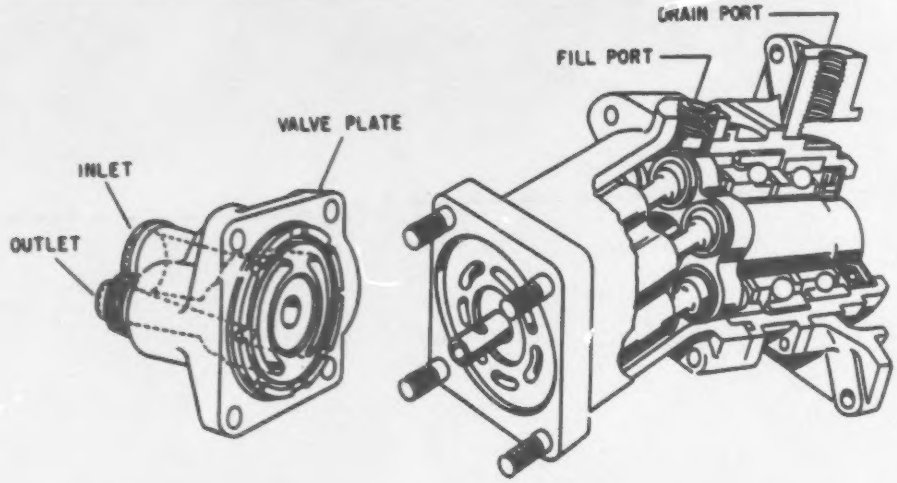
As shown in figure 8-23 (G), the distance the pistons move back and forth in their cylinders depends on the tilt or angle of the tilting plate. In the pump illustrated in figures 8-24 and 8-25. this tilt or angle is fixed by the shape of the housing and therefore is referred to as a fixed displacement or constant displacement pump. Pump output is determined by the angle and, since this angle is fixed, can be changed only by varying the pump speed.

With no tilt at all, no pumping action would occur since the piston would not move back and forth. The distances (A) and (B) in figure 8-23 (G) would be equal, and would remain equal as the assembly rotates. If the angle of tilt given to the tilting plate were reversed, making distance (A) less than distance (B), the pumping action would be reversed. What had been the discharge would now become the intake and vice versa. By adding a mechanism to control the angle of the tilting plate, any variation of delivery can be obtained, from a maximum flow in one direction through zero (no flow) to maximum flow in the opposite direction, although the drive shaft continues to rotate at a constant speed. Axial piston pumps designed with such a controlling device are referred to as variable delivery or variable displacement pumps, defined previously in this chapter.

A variable displacement pump is shown in figure 8-26. This type pump contains either seven or nine single-acting pistons. The pistons reciprocate within cylinder bores which are evenly spaced around a cylinder barrel. (Note that the term barrel, as used in this discussion, actually refers to a cylinder block which contains cylinders.) The piston rods are attached to a socket ring by means of ball-and-socket connections. The socket ring rides on a thrust bearing carried by a casting—the tilting box or plate.

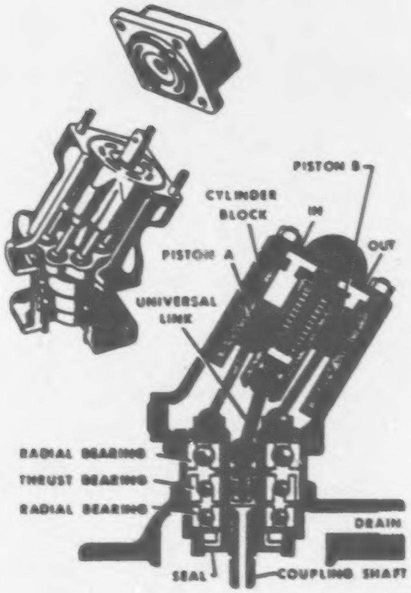
When the tilting plate is at right angles to the shaft, and the pump is rotating, the pistons do not reciprocate; therefore, no pumping action takes place. When the tilting box is tilted away from a right angle, the pistons reciprocate and liquid is pumped.

Since the displacement of this type pump is varied by changing the angle of the tilting box, some means must be used to control the changes of this angle. Various methods are used to control this movement—manual, electric, pneumatic, or hydraulic. The operation of a hydraulically controlled variable displacement pump is



FP.129

Figure 8-24.—Partial cutaway view of axial piston pump.



FP.130

Figure 8-25.—Schematic diagram of axial piston pump.

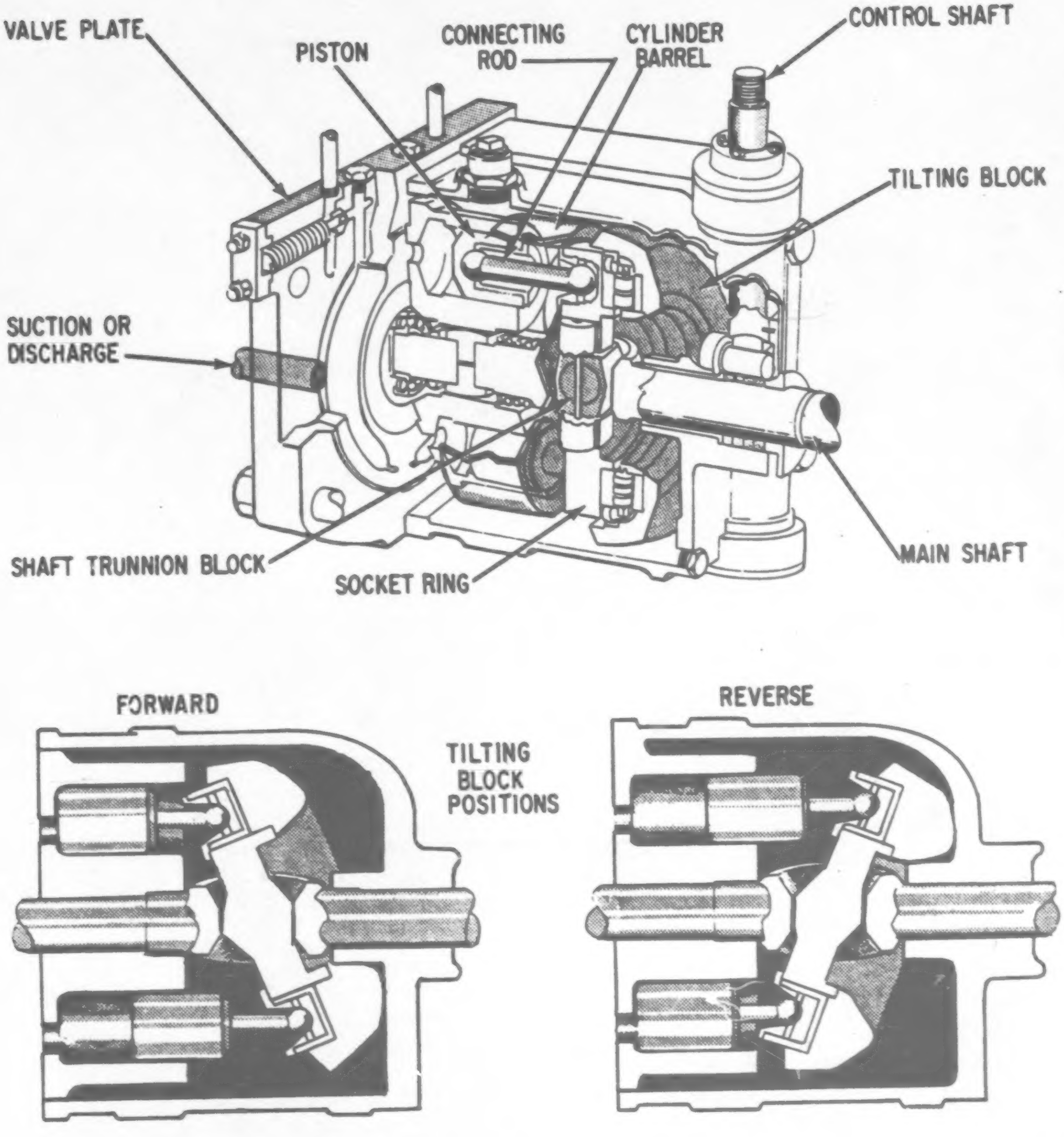
described in the hydraulic power drive system in chapter 13.

Another type of axial piston pump is illustrated in figure 8-27. This type pump is sometimes referred to as an inline pump; however, it is most commonly referred to as a Stratopower pump. Like the axial piston pump described previously, the Stratopower pump is available in either the fixed displacement or the variable displacement type. The pump shown in figure 8-27 is the fixed displacement type.

Two major functions are performed by the internal parts of the fixed displacement Stratopower pump. These functions are mechanical drive and fluid displacement.

The mechanical drive mechanism is shown in figure 8-28. Piston motion is caused by the drive cam displacing each piston the full height of the drive cam each revolution of the shaft. By coupling the ring of pistons with a nutating (wobble) plate supported by a fixed center pivot, the pistons are held in constant contact with the cam face. As the drive cam depresses one side of the nutating plate (as pistons are advanced), the other side of the nutating plate is withdrawn an equal amount, moving the pistons with it. The two creep plates are provided to decrease wear on the revolving cam.

A schematic diagram of the displacement of fluid is shown in figure 8-29. Fluid is displaced by axial motion of the pistons. As each piston advances in its respective cylinder block bore, pressure opens the check and a quantity of fluid is forced past. Combined back pressure and check spring tension closes the check when the piston advances to its foremost position. The low-pressure area occurring in the cylinder during the piston return allows atmospheric


VALVE PLATE
PISTON
CONNECTING ROD
CYLINDER BARREL
CONTROL SHAFT
TILTING BLOCK
SUCTION OR DISCHARGE
SHAFT TRUNNION BLOCK
SOCKET RING
MAIN SHAFT
FORWARD
TILTING BLOCK POSITIONS
REVERSE

FP.131

Figure 8-26.—Variable displacement axial piston pump.

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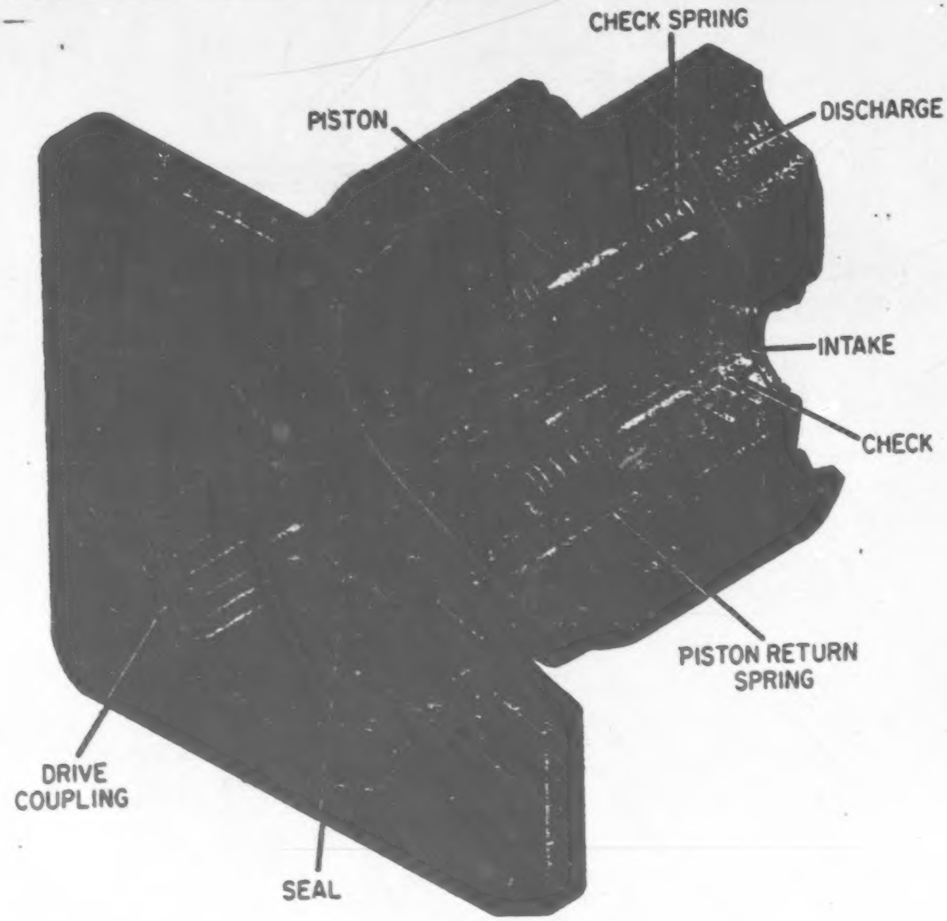
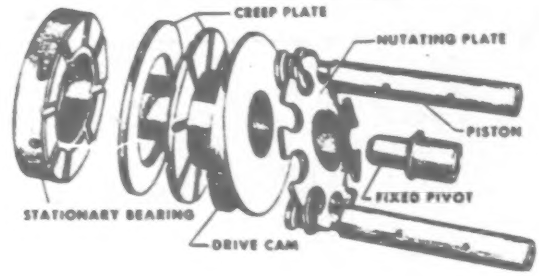

CHECK SPRING
PISTON
DISCHARGE
INTAKE
CHECK
PISTON RETURN SPRING
DRIVE COUPLING
SEAL

FP.132

Figure 8-27.—Cutaway view of Stratopower hydraulic pump—fixed displacement.


CREEP PLATE
NUTATING PLATE
PISTON
FIXED PIVOT
STATIONARY BEARING
DRIVE CAM

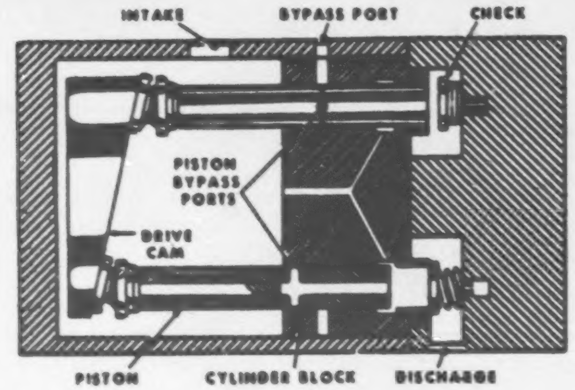
FP.133

Figure 8-28.—Mechanical drive—Stratopower pump.

pressure to force fluid to flow from the intake loading groove into the cylinder.

A fluid flow diagram of the fixed displacement Stratopower pump is illustrated in figure 8-30. Fluid enters the intake port and is discharged through the outlet port by the reciprocating action of the pistons. Fluid is circulated through the back of the pump for cooling and lubricating purposes by the centrifugal action of the drive cam.

The internal features of the variable displacement Stratopower pump are illustrated in figure 8-31. This pump operates similar to the fixed displacement Stratopower pump; however, this pump provides the additional function of automatically varying the volume output.



FP.134

Figure 8-29.—Fluid displacement—Stratopower pump.

This function is controlled by the pressure in the hydraulic system. For example, assume that a pump of this type, rated at 3,000 psi, is providing flow to a 3,000 psi system. When system pressure reaches 3,000 psi and there is no demand on the system, the pump unloads (delivers no flow to the system). The pressure regulation and flow is accomplished by an internal bypass which automatically adjusts delivery of fluid to the demands of the system.

Flow cutoff actually begins before the fluid reaches system pressure. For example, in a 3,000 psi system, flow cutoff begins at approximately 2,850 psi and reaches zero flow (unloads) at 3,000 psi. When the pump is operating in the unload condition, the bypass system provides circulation of fluid internally for cooling and lubrication of the pump.

Four major functions are performed by the internal parts of the variable displacement Stratopower pump. These functions are mechanical drive, fluid displacement, pressure control, and bypass. Two of these functions—mechanical drive and fluid displacement—are identical to those performed by the fixed displacement Stratopower pump.

A schematic diagram of the pressure control mechanism is shown in figure 8-32. Pressure is bled through the control orifice into the pressure compensator cylinder where it moves the compensator piston against the force of the calibrated control (compensator) spring. This motion, transmitted by a direct mechanical linkage, moves sleeves axially on the pistons, thereby varying the time during which the relief holes are covered during each stroke.

Fluid flows through the hollow pistons during the forward stroke, and escapes out the relief holes until they are covered by the piston sleeves. The effective piston stroke (delivery) is controlled by the piston sleeve position. During nonflow requirements, only enough fluid is pumped to maintain pressure against leakage.

During normal pump operation, three conditions may exist—full flow, partial flow, and zero or no flow. During full flow operation (fig. 8-33), fluid enters the intake port and is discharged to the system past the pump checks by the reciprocating action of the pistons. Piston sleeves cover the relief holes for the entire discharge stroke.

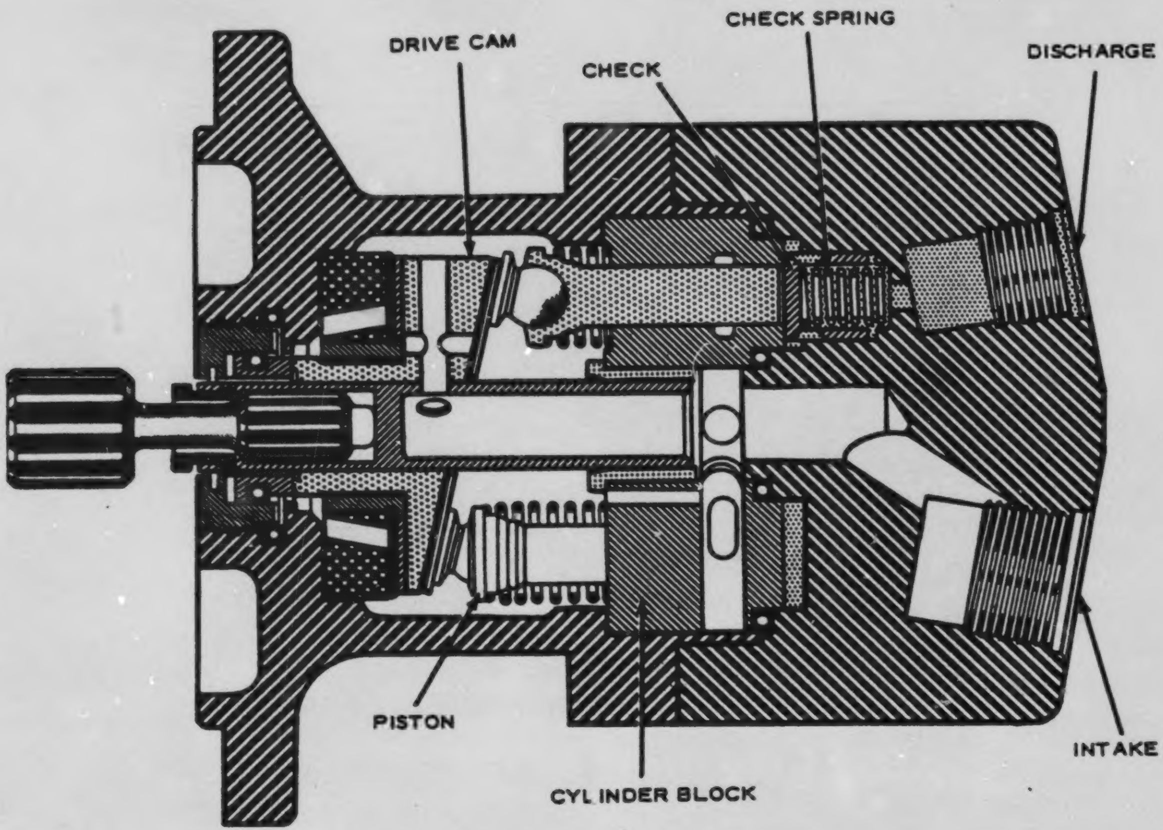
During partial flow, system pressure is sufficient (as bled through the orifice) to move the compensator stem against the compensator spring force.

If system pressure continues to build up, as under nonflow conditions, the stem will be moved further until the relief holes are uncovered for practically the entire piston stroke. The relief holes will be covered only for that portion of the stroke necessary to maintain system pressure against leakage and to produce adequate bypass flow.

The bypass system is provided to supply self-lubrication, particularly when the pump is in nonflow operation. The ring of bypass holes in the pistons are aligned with the bypass passage each time a piston reaches the very end of its forward travel. This pumps a small quantity of fluid out of the bypass passage back to the supply reservoir and provides a constant changing of fluid in the pump. The bypass is designed to pump against a considerable back pressure for use with pressurized reservoirs.

AIR COMPRESSORS

As previously mentioned, compressors are used in pneumatic systems for requirements similar to those required of pumps in hydraulic systems. However, since gases are highly compressible, the gas must be compressed in advance, stored in containers, and then released in sufficient volume and at regulated pressures, from the container into the pneumatic system.



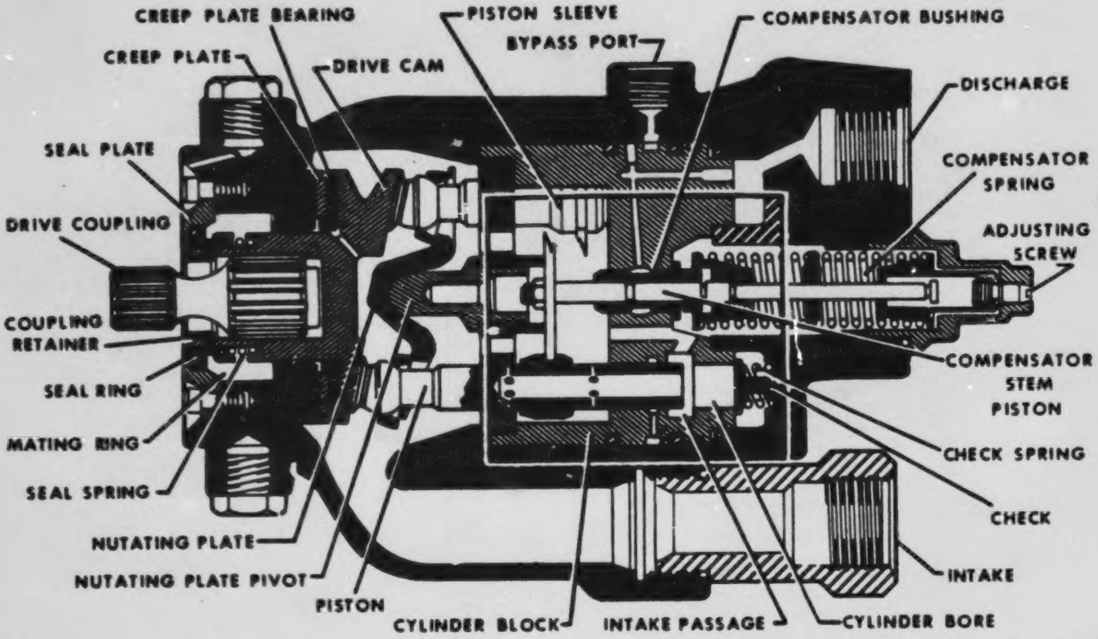
FP.135

Figure 8-30.—Fluid flow—Stratopower pump (fixed displacement).

There are two major types of compressors—the stationary unit and the portable unit. The stationary unit consists of the compressor, receiver, power source, and controls. The gas is compressed and then stored in the receiver where it is piped to the different work areas. Facilities are also provided for charging (filling) bottles and cylinders. The bottles and cylinders are then connected to the pneumatic system and the compressed gas released into the system as required. The portable unit is similar to the stationary unit, except that it is smaller in design and is mounted on wheels so that it can be easily moved to the different work areas. The operation of air compressors is covered in the following paragraphs. Air receivers are discussed in detail in chapter 7.

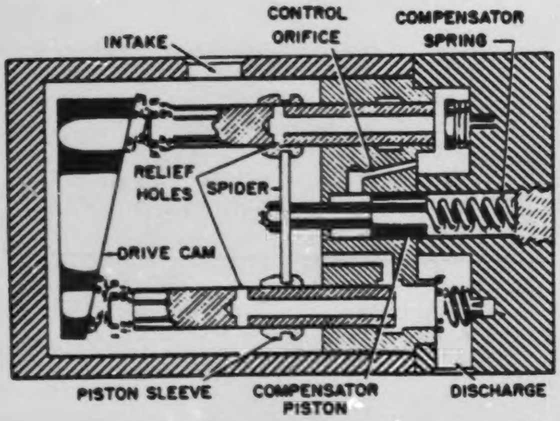
COMPRESSOR CLASSIFICATION

Air compressors are classified in several ways. A compressor may be single-acting or double-acting, single-stage or multistage, and horizontal, angle, or vertical, as shown in figure 8-34. A compressor may be designed so that only one stage of compression takes place within one compressing element, or so that more than one stage takes place within one compressing element. In general, compressors are classified according to the type of compressing element, the source of driving power, the method by which the driving unit is connected to the compressor, and the pressure developed.


CREEP PLATE BEARING
PISTON SLEEVE
COMPENSATOR BUSHING
BYPASS PORT
CREEP PLATE
DRIVE CAM
DISCHARGE
SEAL PLATE
COMPENSATOR SPRING
DRIVE COUPLING
ADJUSTING SCREW
COUPLING RETAINER
COMPENSATOR STEM PISTON
SEAL RING
MATING RING
CHECK SPRING
SEAL SPRING
CHECK
NUTATING PLATE
INTAKE
NUTATING PLATE PIVOT
PISTON
CYLINDER BLOCK
INTAKE PASSAGE
CYLINDER BORE

FP.136

Figure 8-31.—Internal features of Stratopower variable displacement pump.


INTAKE
CONTROL ORIFICE
COMPENSATOR SPRING
RELIEF HOLES
SPIDER
DRIVE CAM
PISTON SLEEVE
COMPENSATOR PISTON
DISCHARGE

FP.137

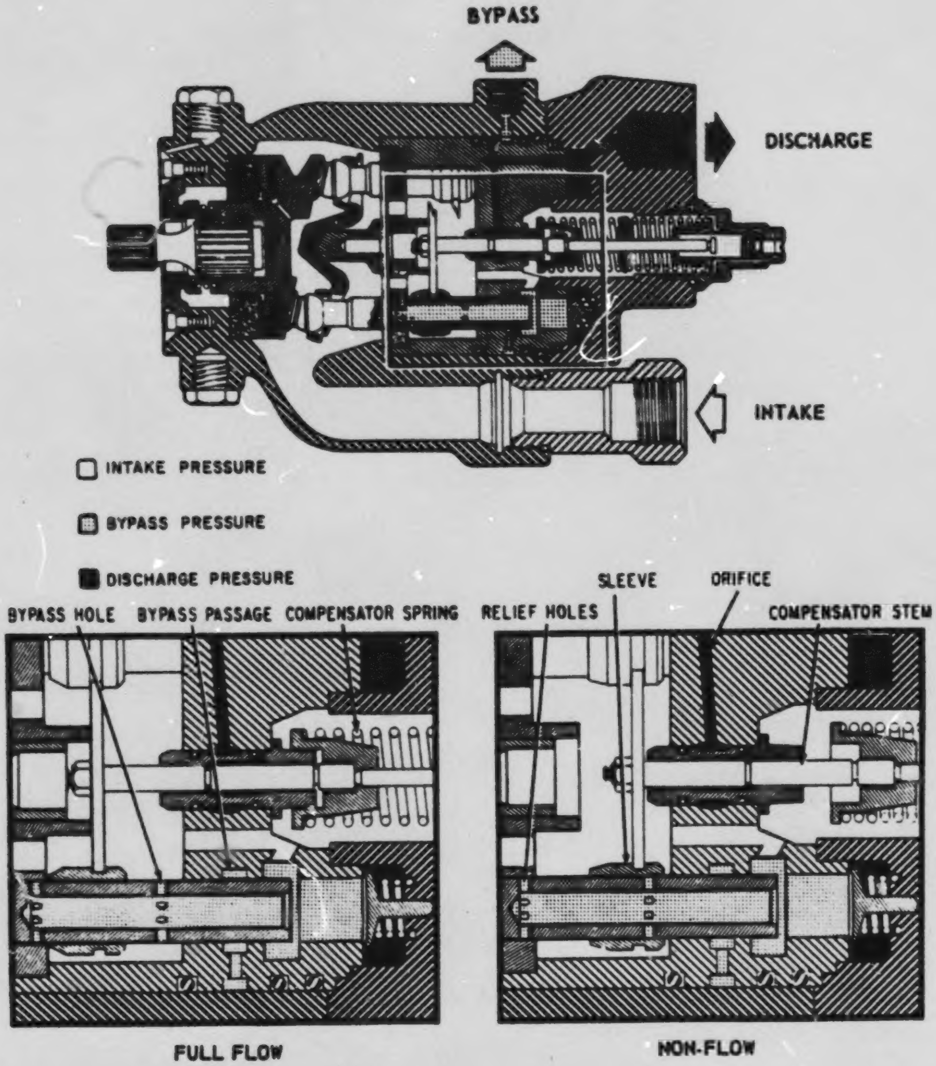
Figure 8-32.—Pressure control mechanism—Stratopower variable displacement pump.

Types of Compressing Elements

Air compressor elements may be of the centrifugal, rotary, or reciprocating types. Most of the compressors used in the Navy have reciprocating elements. (See fig. 8-35.) In this type compressor the air is compressed in one or more cylinders very much like the compression which takes place in an internal combustion engine.

Sources of Power

Compressors are driven by electric motors, internal combustion engines, turbines, reciprocating steam engines, or hydraulic motors. Most of the air compressors in the naval service are driven by electric motors.


BYPASS
DISCHARGE
INTAKE
□ INTAKE PRESSURE
▨ BYPASS PRESSURE
■ DISCHARGE PRESSURE
BYPASS HOLE
BYPASS PASSAGE
COMPENSATOR SPRING
RELIEF HOLES
SLEEVE
ORIFICE
COMPENSATOR STEM
FULL FLOW
NON-FLOW

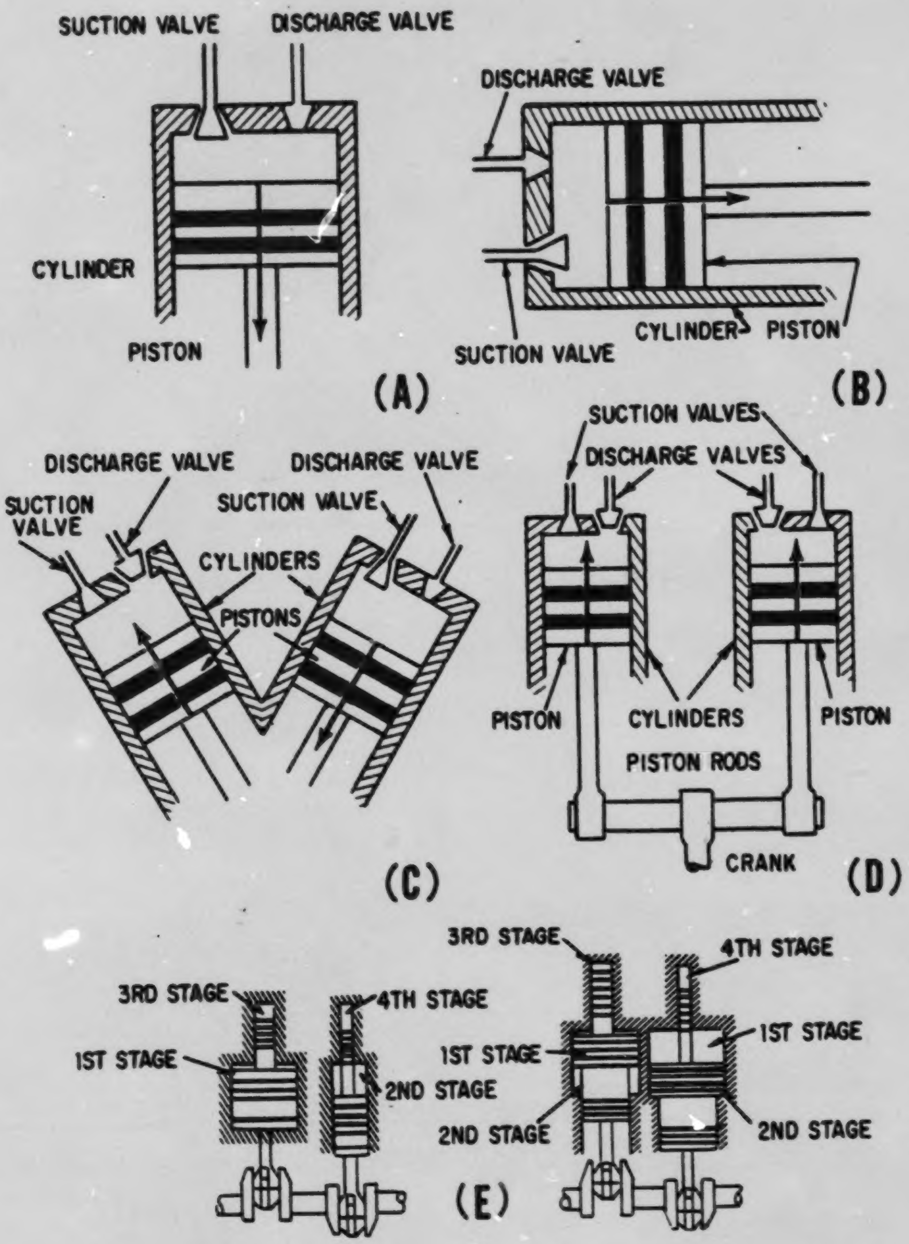
FP.138

Figure 8-33.—Fluid flow—Stratopower variable displacement pump.

Drive Connections

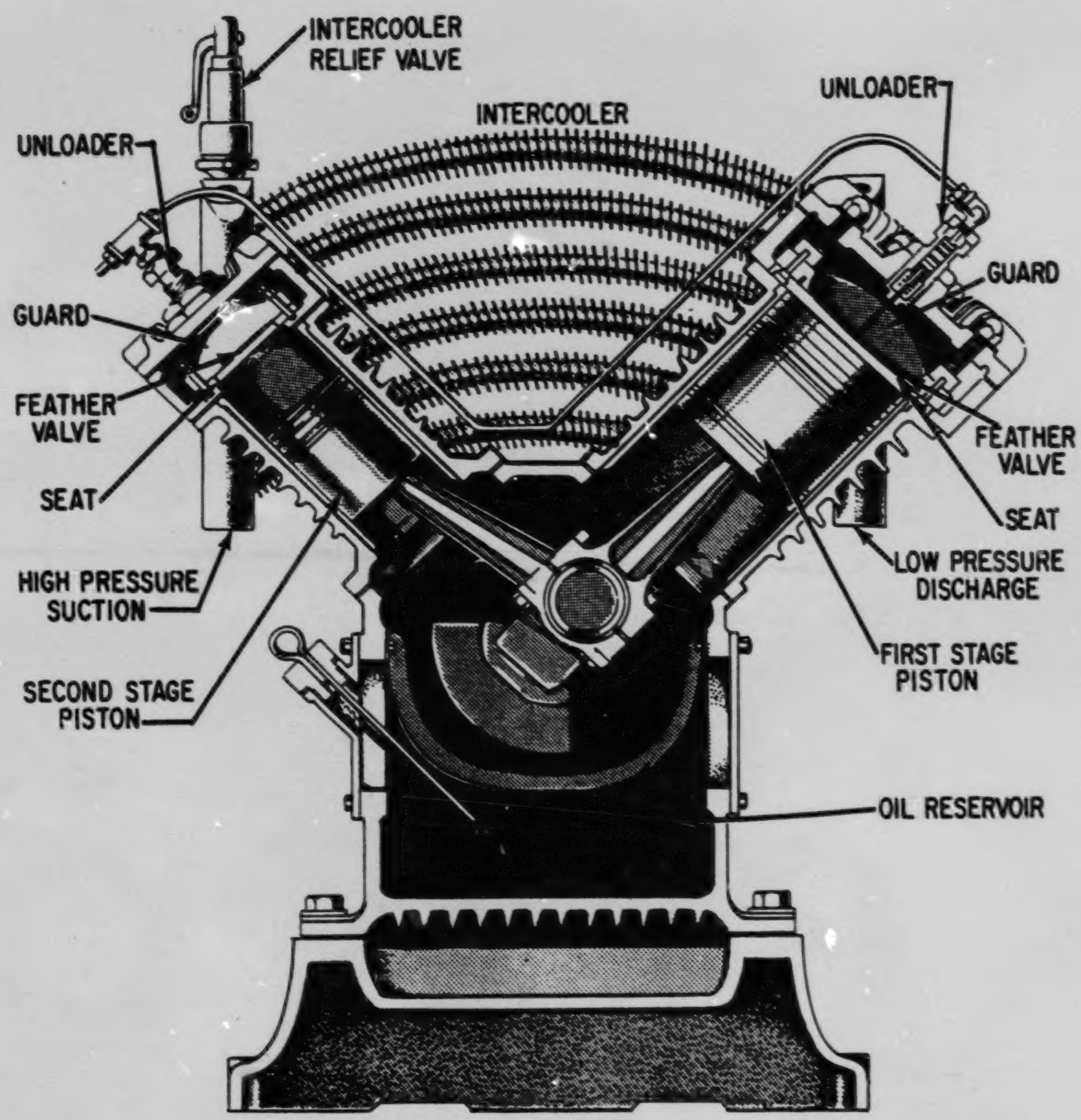
The driving unit may be connected to the compressor by one of several methods. When the compressor and the driving unit are mounted on the same shaft, they are close coupled. Close coupling is often used for small capacity compressors that are driven by electric motors. Flexible couplings are used to join the driving unit to the compressor where the speed of the compressor and the speed of the driving unit can be the same.

V-belt drives are commonly used with small, low-pressure, motor-driven compressors, and some medium-pressure compressors. In some installations, a rigid coupling is used between


SUCTION VALVE
DISCHARGE VALVE
CYLINDER
PISTON
(A)
DISCHARGE VALVE
SUCTION VALVE
CYLINDER
PISTON
(B)
DISCHARGE VALVE
DISCHARGE VALVE
SUCTION VALVE
SUCTION VALVE
CYLINDERS
PISTONS
(C)
SUCTION VALVES
DISCHARGE VALVES
PISTON
CYLINDERS
PISTON
PISTON RODS
CRANK
(D)
3RD STAGE
4TH STAGE
1ST STAGE
2ND STAGE
3RD STAGE
4TH STAGE
1ST STAGE
1ST STAGE
2ND STAGE
2ND STAGE
(E)

FP.139

Figure 8-34.—Types of compressors. (A) Vertical; (B) horizontal; (C) angle; (D) duplex; (E) multistage.


INTERCOOLER RELIEF VALVE
INTERCOOLER
UNLOADER
UNLOADER
GUARD
GUARD
FEATHER VALVE
FEATHER VALVE
SEAT
SEAT
HIGH PRESSURE SUCTION
LOW PRESSURE DISCHARGE
SECOND STAGE PISTON
FIRST STAGE PISTON
OIL RESERVOIR

FP.140

Figure 8-35.—A simple two-stage reciprocating low-pressure air compressor.

the compressor and the motor. When using steam turbine drives, compressors are usually driven through reduction gears.

Pressure Classifications

Compressors are classified as low-pressure, medium-pressure, or high-pressure. Low-pressure compressors are those which provide a discharge pressure of 150 psi or less. Medium-pressure compressors are those which provide a discharge pressure of 151 psi to 1,000 psi. Compressors which provide a discharge pressure above 1,000 psi are classified as high-pressure.

Most low-pressure air compressors are of the two-stage type with either a vertical V (fig. 8-35) or a vertical W arrangement of cylinders. Two-stage, V-type, low-pressure compressors usually have one cylinder that provides the first (low-pressure) stage of compression, and one cylinder that provides the second (high-pressure) stage. W-type compressors have two cylinders for the first stage of compression and one cylinder for the second stage. This arrangement is shown in figure 8-36 (A).

Compressors may be classified according to a number of other design features or operating characteristics.

Medium-pressure air compressors are of the two-stage, vertical, duplex, single-acting type. Many medium-pressure compressors have differential pistons. This type of piston provides more than one stage of compression on each piston. (See fig. 8-36.)

Modern air compressors are generally motor-driven (direct or geared), liquid or air cooled, four-stage, single-acting units with vertical or horizontal cylinder arrangement. Cylinder arrangements for high-pressure air compressors utilized in the naval service are illustrated in figure 8-36 (B). Small capacity high-pressure air systems may have three-stage compressors. High capacity air systems may be equipped with five- or six-stage compressors.

RECIPROCATING AIR COMPRESSORS

An air compressor assembly includes all the associated equipment required for delivering filtered, oil and moisture free compressed air as required for the operation of various units. The complete unit normally includes the compressor, filter and moisture separator assembly, an adjustable relief valve assembly, a control system, and an air receiver with a pressure gage. (See figure 8-37.)

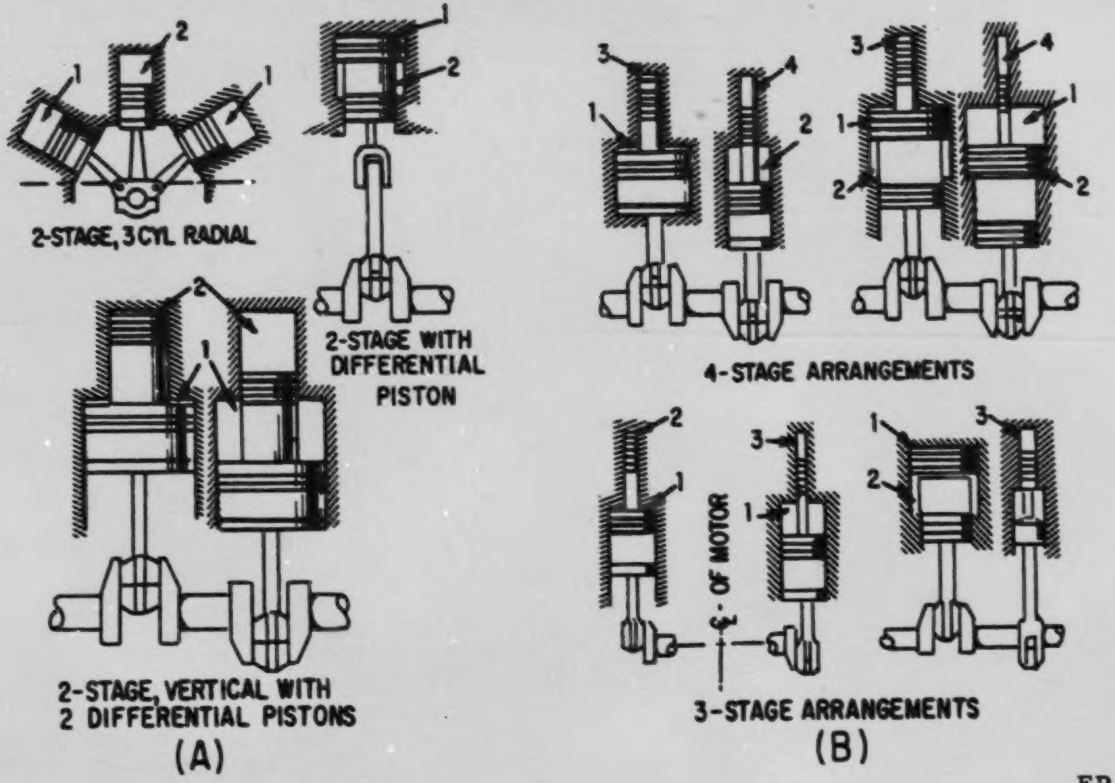
Most reciprocating compressors are similar in design and operation. The following discussion relates to the radial, three-stage, piston type, high-pressure air compressor.

Principles of Operation

This air compressor consists of three piston type air pumps connected in series. Therefore, the process of compressing ambient air (see glossary) to a relatively high pressure is accomplished in three stages. Each compressor stage consists of a cylinder, a reciprocating piston, an intake valve mechanism, and an exhaust valve mechanism. The reciprocating pistons are connected to, and actuated by, a master rod assembly attached to a shaft that is coupled to the power source by a flexible coupling.

The intake and exhaust valves are usually hardened steel discs, carefully ground and lapped to seat snugly against a shoulder at the end of the cylinder bore (chamber). The valves are held against the valve seat by a tempered steel spring. As the piston travels downward, the cylinder bore forward of the piston is at reduced pressure and the intake valve lifts from its seat and allows air to enter the cylinder. As the piston travels upward, the intake valve closes and the air is compressed until the pressure overcomes the resistance of the exhaust valve spring. The exhaust valve is then lifted from its seat and the compressed air in the cylinder escapes through the outlet fitting into the interstage tubing.

To compensate for the volumetric decrease of the air as it is compressed, the cylinder bores and piston displacement of the three stages are progressively decreased. The first-stage cylinder is the largest and, therefore, receives a relatively large volume of ambient air and compresses it into a smaller volume for delivery to the medium size second-stage cylinder. Here, the compression cycle is repeated. The supercharged inlet air is further compressed to a higher pressure and applied to the third-stage cylinder. Here, the compression cycle is completed as the air is


1
2
1
2-STAGE, 3CYL RADIAL
1
2
2-STAGE WITH DIFFERENTIAL PISTON
2
1
2-STAGE, VERTICAL WITH 2 DIFFERENTIAL PISTONS
(A)
3
1
4
2
3
1
2
4
1
2
4-STAGE ARRANGEMENTS
2
1
3
1
℄ - OF MOTOR
1
2
3
3-STAGE ARRANGEMENTS
(B)

FP.141

Figure 8-36.—Air compressor cylinder arraggement. (A) Low- and medium-pressure cylinders; (B) high-pressure cylinders.

compressed to its ultimate delivery pressure. (This is an application of Boyle's law discussed in chapter 2.)

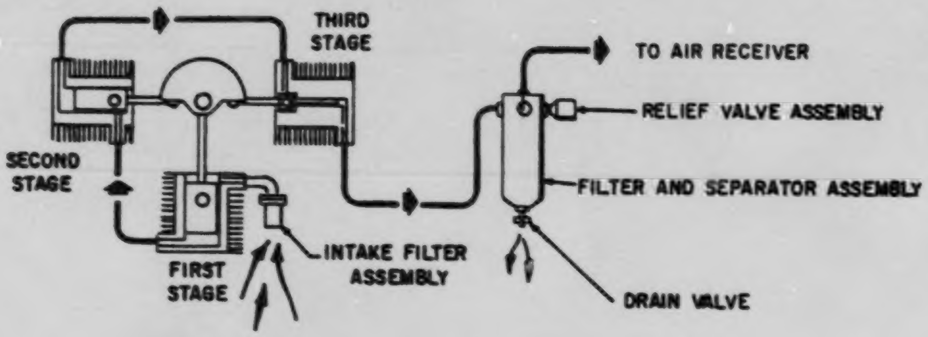
NOTE: These cycles compare with the number of stages of a particular compressor. For example, a six-stage compressor has six such stages.

Compressor Lubrication

Unlike hydraulic pumps, which are lubricated by the liquid of the system passing around the moving parts, the pneumatic compressor requires a lubrication system for its moving parts.

Most low-pressure and medium-pressure compressors are lubricated by a simple but effective combination of pressure, splash, and mist principles. Normally, the compressor base is used as the oil sump and oil pump housing. The oil level can be measured by a dip stick, or, in some compressors, by an oil level sight gage that is mounted on the outside of the base.

During compressor operation, sump oil enters the pump cylinders through ports in the cylinder walls on the up stroke of the piston. On the down stroke, the piston descends past the ports, preventing the escape of oil. The oil trapped in the cylinder is forced through a spray tube and is directed against the rapidly moving master rod. The impact forms a fine mist of oil which fills the interior of the crankcase and provides lubrication of the master rod, bearings, pistons, connecting links, and other internal parts. Internal lubrication of the cylinders and valve mechanisms is aided by the small quantity of vapor drawn into the first-stage cylinder from the crankcase and



FP.142

Figure 8-37.—Air compressor assembly.

passed on to the second and third stages through the interstage connecting tubes.

Lubrication of high-pressure air compressor cylinders is generally accomplished by means of an adjustable mechanical force-feed lubricator, which is driven from a reciprocating or a rotary part of the compressor. Oil is fed from the cylinder lubricator, by separate feed lines, to each cylinder. A check valve is installed at the end of each feed line to keep the compressed air from forcing the oil back into the lubricator. Lubrication begins automatically as the compressor starts up. The amount of oil that must be fed to the cylinder depends upon the cylinder diameter, the cylinder wall temperature, and the viscosity of the oil.

Lubrication of the other internal parts of most modern high-pressure compressors, and some medium- and low-pressure compressors, is accomplished by an oil pump. The pump (usually of the gear type) is attached to the compressor and is driven by the compressor shaft. The pump is supplied with oil from the compressor reservoir (crankcase) and delivers it, through a filter, to an oil cooler. From the cooler, the oil is distributed to the top of each main bearing, to spray nozzles for reduction gears, and to outboard bearings. The crankshaft is drilled so that oil fed to the main bearings is picked up by the main bearing journals and carried to the crank journals. The connecting rods contain passages which conduct lubricating oil from the crank bearings up to the wrist pin bushings. As oil leaks out from the various bearings, it drips back to the oil sump (in the base of the compressor) and is recirculated. Oil from the outboard bearings is carried back to the sump by drain lines.

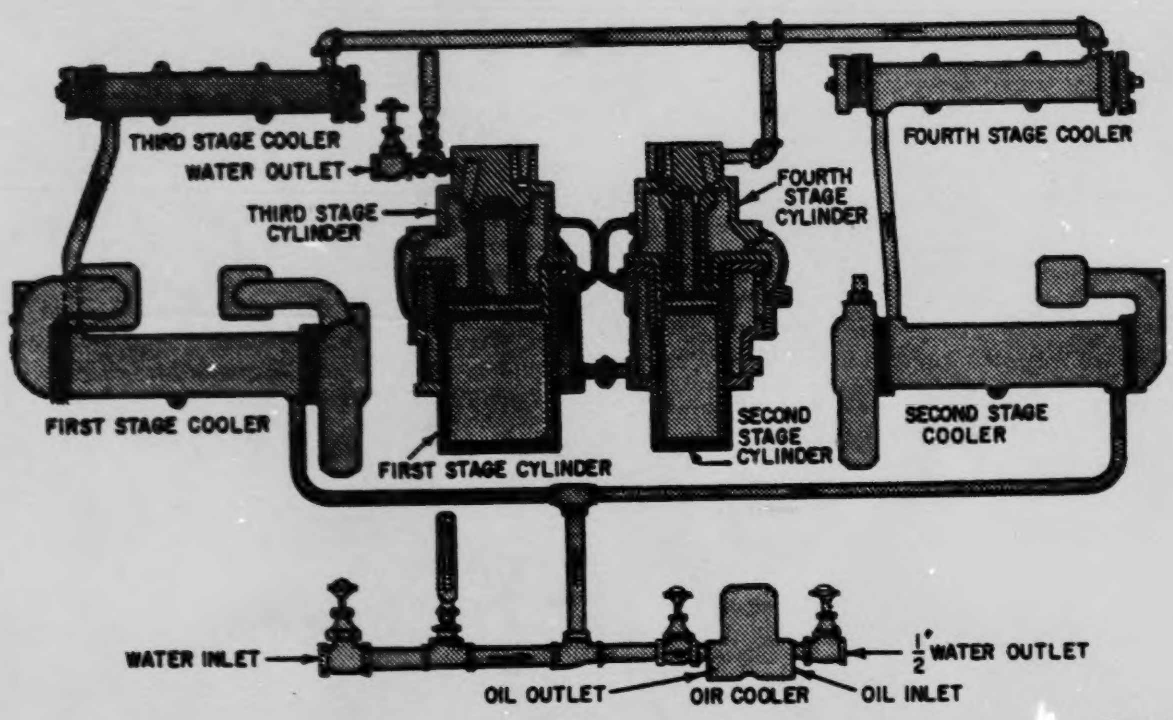
The discharge pressure of lubrication oil pumps varies with different pump designs. A relief valve, fitted to each pump, functions when the discharge pressure exceeds the pressure for which the valve is set. When the relief valve lifts, excess oil is returned to the sump.

Cooling

In some low-pressure air compressors, the heat, which normally results from rapid compression of a gas, is dissipated before the temperature attains a troublesome level. This is accomplished by using aluminum cylinders with integral cooling fins and a fan which blows cooling air past the cylinders and interstage tubing. This type of cooling is sufficient for most low-pressure air compressors when operated in well-ventilated spaces.

Most high-pressure and medium-pressure compressors aboard ship are cooled by sea water supplied from the ship's fire, flushing, or water service mains. The cooling water is generally available to each unit through at least two sources. Compressors located outside the large machinery spaces are generally equipped with an attached circulating water pump as a standby source of cooling water.

The cooling water is circulated through the compressor in much the same manner as an automobile engine. The path of water in the cooling water system of a typical four-stage


THIRD STAGE COOLER
WATER OUTLET
THIRD STAGE CYLINDER
FOURTH STAGE CYLINDER
FOURTH STAGE COOLER
FIRST STAGE COOLER
FIRST STAGE CYLINDER
SECOND STAGE CYLINDER
SECOND STAGE COOLER
WATER INLET
OIL OUTLET
OIR COOLER
OIL INLET
$\frac{1}{2}$" WATER OUTLET

FP.143

Figure 8-38.—Cooling water system in a typical multistage air compressor.

compressor is illustrated in figure 8-38. Not all systems have identical paths of water flow; however, in systems equipped with oil coolers, it is important that the coldest water is available for the cooler. Valves are usually provided so that the water to the cooler can be controlled independently of the rest of the system. Thus, oil temperature may be controlled without harmfully affecting other parts of the compressor.

Next in importance are the intercoolers and after coolers (discussed later), then the cylinder jackets and heads. High-pressure air compressors require from 6 to 25 gallons of cooling water per minute, while medium-pressure compressors require from 10 to 20 gallons per minute.

When sea water is used as the cooling agent, all parts of the circulating system must be of corrosion-resisting materials. The cylinders and heads are therefore composed of gun metal or valve bronze composition, with water jackets cast integral with the cylinders. Each cylinder is fitted with a liner of special cast iron or steel to withstand the wear of the piston. Whenever practicable, the cylinder jackets are fitted with handholes and covers so that water spaces may be inspected and cleaned. Jumper lines are generally used to make water connections between the cylinders and heads, since these prevent any possibility of leakage into the compression spaces. In some compressors, however, the water passes directly through the joint between the cylinder and the head. With this latter type, extreme care must be taken to insure that the joint is properly sealed to prevent leakage which, if allowed to continue, would ruin both the cylinder liner and the piston.

The intercoolers and aftercoolers remove the heat generated during compression and cause the condensation of any vapor that might be present. It is important that this condensation be drained at regular intervals to prevent carryover into the next stage, accumulation at low points, water hammer, freezing or bursting of pipes in exposed locations, faulty operation of pneumatic systems and components, and possible damage to electrical apparatus where air is used for cleaning. The removal of heat is also required for economical compression. During compression the temperature of the air is increased, thus causing the air to expand to a larger volume which, in turn, requires a corresponding increase of work to compress it. (The effect of changes in temperature on compressed gas is discussed in chapter 2.) Multistaging and cooling of the air between stages reduce the power requirement for a given capacity. The intercooling reduces the maximum temperature in each cylinder and thereby reduces the amount of heat that must be removed by the water jacket at the cylinder. Also, the resulting temperature in the cylinder insures good lubrication of the piston and the valves. Both the intercoolers and the aftercoolers are of the same general construction, except that the aftercoolers are designed to withstand a higher working pressure that the intercoolers.

Water-cooled intercoolers may be of the straight tube and shell type or, if size permits, may be of the coil type. In coolers with air pressure above 250 psi, the air flows through the tubes. Suitable baffles are provided in tubular coolers to deflect the air or water in its course through the cooler. In coil type coolers the air passes through the coil, with the water flowing around the outside.

Air-cooled intercoolers and aftercoolers may be of the radiator type or may consist of a bank of finned copper tubes located in the path of blast air provided by the air compressor.

Automatic temperature shutdown devices are fitted on all recent designs of high-pressure air compressors. Thus, if the cooling water temperature rises above a safe limit, the compressor will stop and will not restart automatically. Some compressors are fitted with a device that will shut down the compressor if the temperature of the air leaving any stage exceeds a preset value.

Compressor Assembly Components

As previously stated certain other components are usually considered as part of the compressor assembly. A brief description of these components is given in the following paragraphs. They are described in more detail in other sections of the manual, as indicated.

A filter and a moisture separator are incorporated in the line between the compressor and the receiver tank. Their purpose is to remove as much dirt and moisture as possible before the air enters the system. Filters and separators are discussed in chapter 7.

An air receiver or reservoir is installed in or near each space housing air compressors. The receiver acts as a supply tank and a storage tank for the pneumatic system. Air receivers are explained in chapter 7.

An unloading system that removes the compression load from the compressor while the unit is starting and automatically applies the load after the unit reaches operating speed is installed in most systems. Unloading valves are covered in more detail in chapter 10.

A pressure relief valve is installed in the assembly. It exhausts compressor discharge air to the atmosphere when the pressure in the equipment being charged exceeds a predetermined maximum value. Pressure relief valves are described in chapter 10.

CHAPTER 9

CONTROL AND MEASUREMENT OF FLOW

It is all but impossible to design a practical fluid power system without some means of controlling the volume and pressure of the fluid and directing the flow of fluid to the operating units. This is accomplished by the incorporation of different types of valves at various points in the system. Different types of valves used in fluid power systems are discussed in this chapter and chapters 10 and 11. A brief introduction to valves, including their classification and application, is covered in the first part of this chapter. This is followed by detailed descriptions and illustrations of those valves which are used to control the flow of fluids.

Some fluid power systems require devices for measuring the quantity or rate of flow through the system. The latter part of this chapter is devoted to various types of flowmeters used for measuring the flow of fluids.

INTRODUCTION TO VALVES

An often quoted definition of a valve is "an engineered obstruction in a pipe." Although this definition is technically correct, a more precise definition is: A valve is any device by which the flow of fluid may be started, stopped, or regulated by a movable part which opens or obstructs passage. As applied to fluid power systems, valves are used for controlling the flow of the fluid, the pressure of the fluid, and the direction of the fluid flow.

Valves must be accurate in the control of fluid flow and pressure and the sequence of operation. Usually, no packing is used between the valving element and the valve seat, since fluid leakage is reduced to a negligible quantity by precision machined surfaces, resulting in carefully controlled clearances. (Packing is required around valve stems, between lands of spool valves, etc.) This is another very important reason for using only the recommended fluid in the system and for keeping the fluid clean. Oxidation, rust particles, and other foreign materials such as dust, sand, lint, etc., can cause considerable damage to precision valves. This contamination will cause valves to stick, may plug small orifices, or cause abrasion of the valving surfaces, resulting in leakage between the valve element and valve seat when the valve is in the closed position. Any one of these can result in inefficient operation or complete stoppage of the equipment.

Valves may be controlled manually, electrically, pneumatically, mechanically, hydraulically, or by combinations of two or more of these methods. In some systems the entire sequence of operation of the most complicated equipment may be automatic. The method of control depends upon many different factors. The purpose of the valve, the design and purpose of the system, the location of the valve within the system, and the availability of the source of power are some of the factors that determine the method of control.

CLASSIFICATION OF VALVES

Valves are sometimes classified according to their method of operation—simple, compound, or directional. A simple valve requires only a single internal motion for its operation. For example, fluid acting on one side of the valving element opens it against the resistance of gravity or spring tension; or the valve is controlled manually by turning a screw so that the passage for the fluid is opened or closed. A compound valve involves a combination of internal motions for its operation. Directional valves are used to control the direction of the flow of fluid along two or more paths.

Probably, the most common method of classifying valves is according to their purpose—

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flow control, pressure control, and directional control. This method of classification is very similar to the method discussed previously. As a general rule, simple valves include those which control flow; compound valves include those which control pressure; and, of course, directional valves control the direction of flow.

All the types of valves available for fluid power systems are too numerous to describe within the scope of this training manual. Most valves, however, are variations of these three fundamental classes—flow control, pressure control, and directional control. Several representative types in each class are described and illustrated in this manual. Flow control valves are discussed in this chapter. Pressure control valves are described in chapter 10, while directional control valves are covered in chapter 11.

APPLICATIONS

Each type of valve used in fluid power systems has a specific purpose or, in some applications, a combination of different purposes. These applications and purposes are discussed in more detail as the different valves are described in this chapter and in chapters 10 and 11. In general, however, the applications of valves according to their classification, are briefly described in the following paragraphs.

Flow control valves are used in fluid power systems to open and close a line to flow or to control the rate of flow through the lines. They are sometimes used as ON and OFF valves to isolate circuits of the system during certain operations.

The uses of pressure control valves include the regulation of system pressure, the protection of the system and components from pressure overload, and the control of the sequence of operation of certain components in some systems.

Among other applications, directional control valves are used to control the paths of the fluid to operating components. For example, these valves are used to control the direction of rotation of actuating motors and the direction of movement of actuating cylinders.

FLOW CONTROL VALVES

A typical example of a valve used to control flow is the ordinary water faucet. It is normally in the closed position allowing no flow. It can be fully opened allowing full flow. The rate of flow is varied by turning the faucet handle clockwise or counterclockwise, which changes the size of the opening of the faucet. Although some of the flow control valves used in fluid power systems are similar to the water faucet, others are more complex in design and operation. Some of the different types of flow control valves commonly used in fluid power systems are described in the following paragraphs.

PLUG VALVES

A plug valve, sometimes referred to as a cock, consists of a hollow cylindrical shaped body into which is fitted a tapered cylindrical plug. Figure 9-1 shows an exploded view of a plug valve, including a cross-sectional view of the body. The top of the plug extends up through the gland, and can be turned with a wrench. In most plug valves, the plug terminates in a handle for manual control of the valve.

The body of the valve is secured in the line with holes or ports in the wall of the cylindrical body aligned with the flow of fluid through the line. The plug, which also contains holes or ports, fits snugly into the valve body. When the plug is open the ports of the plug are in line with the ports of the body, allowing fluid to flow through the valve. (See fig. 9-2.) Flow is stopped by a quarter turn of the plug, which aligns the solid areas of the plug with the ports in the body. The top of the plug or the handle is usually marked by some method to indicate whether the valve is open or closed.

Although the inside surfaces of plug valves are machined to give close contact, the meeting of metal with metal offers the danger of seizing. When plug valves stand normally in an open position, the parts of the plug that provide the seal are not directly in contact with the fluid; but when the valve is normally closed the fluid will act on only one side of the sealing surface. Under ordinary conditions, however, plug valves can be easily opened or closed.

Plug valves are used as fully ON or fully OFF valves. They are not designed to be used in a semiopen position; that is, to throttle or vary the volume of flow. This is especially true if grooves in the walls of the body are filled with packing to separate metal from metal. In a partially open position, this packing would

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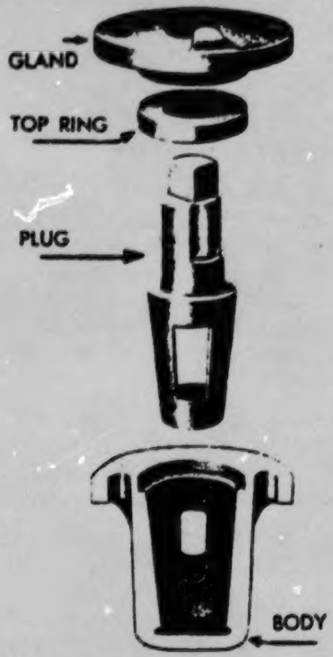
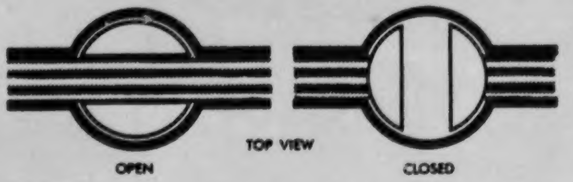


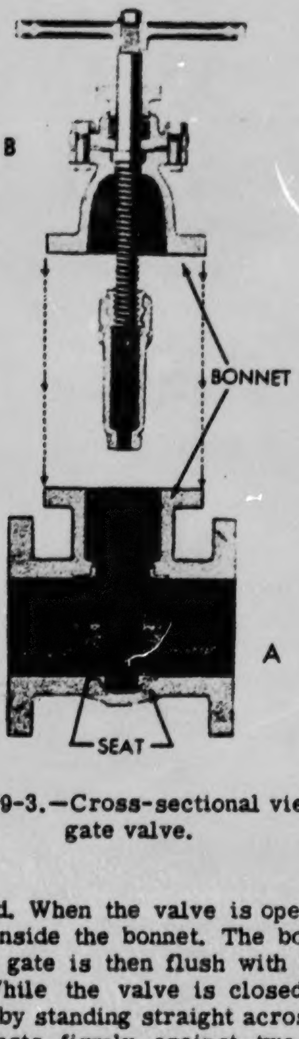
FP.144

Figure 9-1.—Plug valve.



FP.145

Figure 9-2.—Operation of plug valve.



FP.146

Figure 9-3.—Cross-sectional view of gate valve.

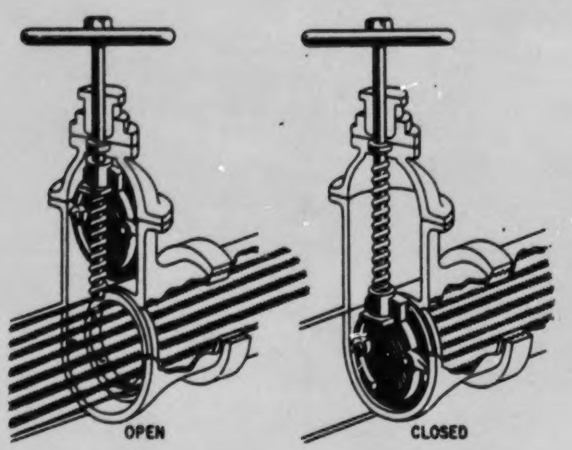
eventually wear away. In any event, unequal wear is encouraged if the valve remains in the partly open position for any length of time.

Plug valves have a limited use in fluid power systems. Small plug valves are sometimes used in hydraulic systems to free the system of air. The valve is opened so that the air can escape. When the liquid begins to flow continuously the valve is closed. Plug valves are also used in pneumatic systems to drain condensation from the system.

GATE VALVES

In the gate valve, flow is controlled by means of a wedge or gate, the movement of which is usually controlled with a handwheel. By turning the handwheel, the wedge or gate can be moved up and down across the line of flow to open and close the passage. Figure 9-3 illustrates the principal elements of the gate valve in cross section. Part (A) shows the line connection and the outside structure of the valve body, while (B) shows the wedge or gate inside the valve and the stem to which the gate and handwheel are attached. When the valve is open, the gate stands up inside the bonnet. The bottom surface of the gate is then flush with the wall of the line. While the valve is closed, the gate blocks flow by standing straight across the line, where it rests firmly against two seats extending completely across the line.

Gate valves permit straight flow and offer little or no resistance to the flow of fluid when the valve is completely open. Gate valves are intended for use as fully open or fully closed



FP.147

Figure 9-4.—Operation of gate valve.

valves. If the valve is partly open, the face of the valve stands in the flow of fluid. This flow will act on the face of the valve causing it to erode. For this reason, gate valves should not be used to restrict or throttle the rate of flow.

Two different types of gates are used in the construction of gate valves. One type is a solid or hollow wedge. This type is satisfactory for small valves in low-pressure systems. However, wedges are sometimes difficult to tighten and will leak when slightly worn. The other type consists of two facing discs. By using discs a better closure is provided, since the discs are forced apart, snug against the valve seats, as they are moved into position. One arrangement for accomplishing this is shown in figure 9-4. One of the two facing discs, composing the valve, has been removed to show how the valve is constructed. Two cams with arms extending outward stand opposite each other on slanting surfaces in the space between the discs. As the discs move into the closed position, the arm of each cam engages a lug on the body of the valve and is turned on the slanting cam bearing surface, forcing the discs against the valve gates during closure.

Gates valves are available in different types of stem connections. Figure 9-5 illustrates three different types. In figure 9-5 (A), the stem screws down into the valve gate as the valve is opened. In this type the stem does not rise or fall outside the body of the valve as the valve is opened or closed. In figure 9-5 (B), the stem rises outside the valve as the valve is opened, but the stem screw operates inside the body of the valve. In figure 9-5 (C), the stem screw operates at the level of the handwheel, so that the stem rises independently of the wheel as the valve is opened. This is called the outside-screw-and-yoke type valve.

Valves with rising stems are used when it is important to know by immediate inspection whether the valve is open or closed. The nonrising stem type is least likely to leak, and requires less space.

Gate valves should be opened or closed slowly. Difficulty in opening and closing the valve may be caused by high fluid pressure acting against the gate. The gate should not be forced against the seat. If the valve fails to seat properly, it should be opened slightly and then closed again. If it still fails to seat, the system must be shut down and the valve disassembled to locate and correct the trouble.

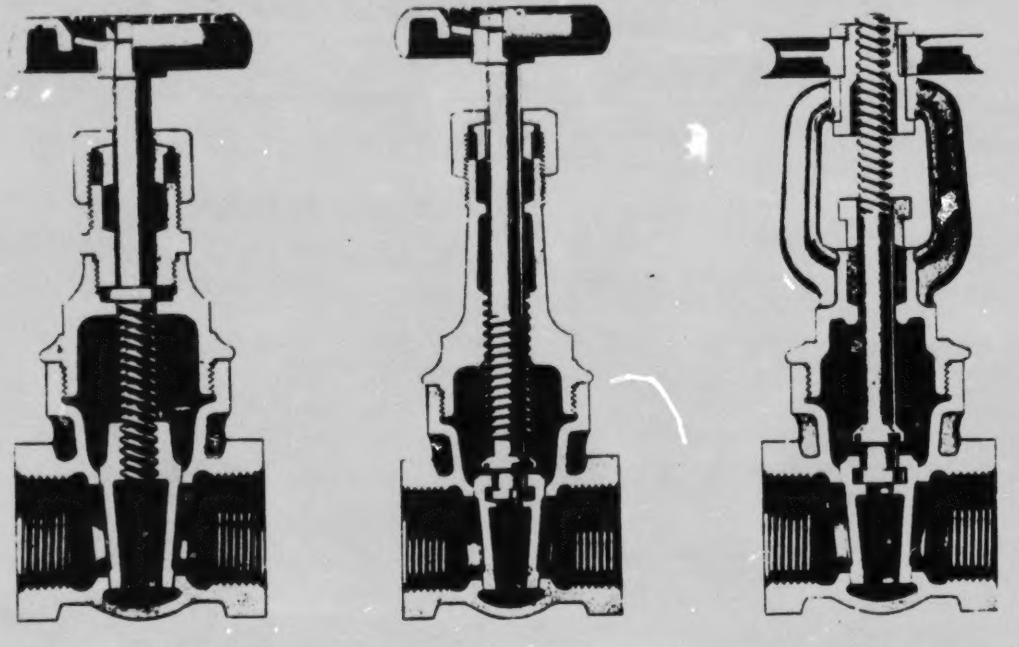
GLOBE VALVES

Globe valves derive their name from the globular shape of their bodies. It should be noted, however, that other types of valves may also have globular-shaped bodies; hence, the name may tend to be misleading. It is the internal structure of the valve, rather than the external shape, that distinguishes one type of valve from the other.

The controlling member of the globe valve, called the disc, is attached directly to the end of the stem. The valve is closed by turning the valve stem in until the disc is seated into the valve seat. Since the fluid flows equally on all sides of the center of support when the valve is open, there is no unbalanced pressure on the disc to cause uneven wear. The operation of the globe valve is illustrated in figure 9-6.

The moving parts of a globe valve consist of the disc, valve stem, and the handwheel. Figure 9-7 (A) is an exploded view of a globe valve. The stem, which connects the handwheel and the disc, is threaded and fits into the threads in the valve bonnet. Discs are available in various designs. (See fig. 9-7 (B).)

When the valve is closed, the valve disc rests against the valve seat, preventing fluid from flowing through the valve. The edge of



(A) (B) (C)

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Figure 9-5.—Types of gate valves.

the disc and the seat are very accurately machined so that they form a tight seal when the valve is in the closed position. When the valve is open, the fluid flows through the space between the edge of the disc and the seat. The rate at which the fluid flows through the valve is regulated by the position of the disc in relation to the seat. The valve must always be installed with the pressure against the face of the disc.

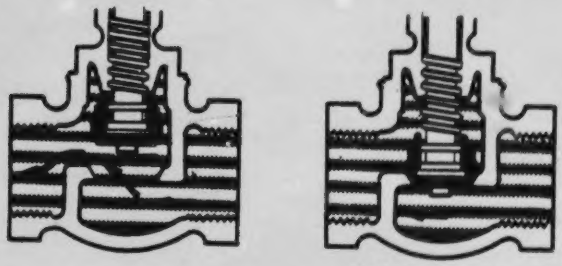
The globe valve is commonly used as a fully open or fully closed valve. This valve may also be used as a throttle valve to control the rate of flow. However, since the seating surface is a relatively large area, this valve is not suitable as a throttle valve where fine adjustments are required in controlling the rate of flow.

The globe valve should never be jammed in the open position. After a valve has been fully opened, the handwheel should be turned toward the closed position approximately one-half turn. Unless this is done, the valve is likely to seize in the open position making it difficult, if not impossible, to close the valve. Many valves have been damaged in this manner. Another reason for not leaving globe valves in the fully open position is that it is sometimes difficult to determine if the valve is open or closed. If the valve is jammed in the open position, the stem may be damaged or broken by someone who thinks the valve is closed, and attempts to open it.

NEEDLE VALVES

Needle valves are similar in design and operation to the globe valve. Instead of a disc, a needle valve has a long tapered point at the end of the valve stem. A cross-sectional view of a needle valve is illustrated in figure 9-8.

The long taper of the valve element permits a much smaller seating surface area as compared to the globe valve; therefore, the needle valve is more suitable as a throttle valve where fine adjustments are required in controlling the rate of flow. Needle valves are used to control flow into delicate gages, which might be



FP.149

Figure 9-6.—Operation of a globe valve.

damaged by sudden surges of fluid under pressure. Needle valves are also used to control end operation of a work cycle, where it is desirable that a work motion be brought slowly to a halt; and at other points where precise adjustments of flow are necessary and where a small rate of flow is desired.

Although many of the needle valves used in fluid power systems are of the manually operated type illustrated in figure 9-8, modifications of this type valve are often used as variable restrictors, described in the next section.

RESTRICTORS

Restrictors, sometimes referred to as orifices, are used in fluid power systems to limit the speed of movement of certain actuating devices. They do so by serving as restrictions in the line, thereby limiting the rate of flow. Figure 9-9 shows an example of a typical restrictor. This type is referred to as a fixed restrictor.

Some types of restrictors are constructed so that the amount of restriction can be varied. One type of variable restrictor is illustrated in figure 9-10. This type is simply a modification of the needle valve, previously described. Instead of a handwheel control, this valve is constructed so that it can be preadjusted to alter the time of operation of a particular subsystem. It can be adjusted to conform to the requirements of a particular system. This permits the same type valve to be used in different systems.

ORIFICE CHECK VALVES

Check valves are described in more detail in chapter 11, since their purpose is to control the direction of flow. However, they are used in conjunction with some types of flow control valves. The orifice check valve is an example, and is used in fluid power systems to allow

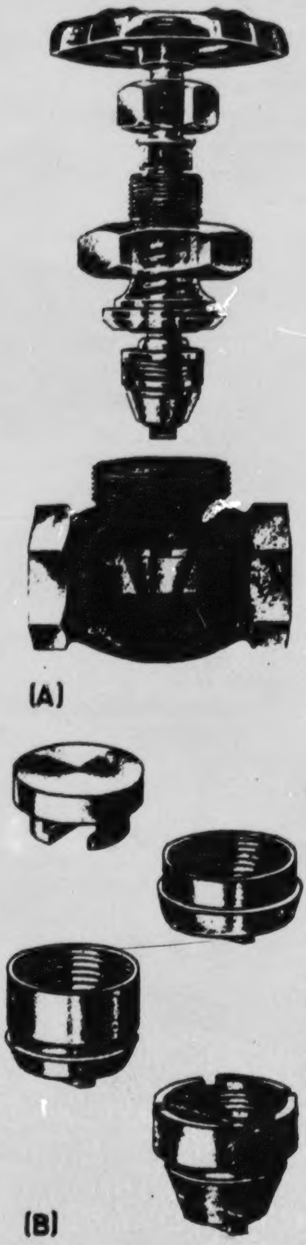


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Figure 9-7.—Globe valve with various types of discs.

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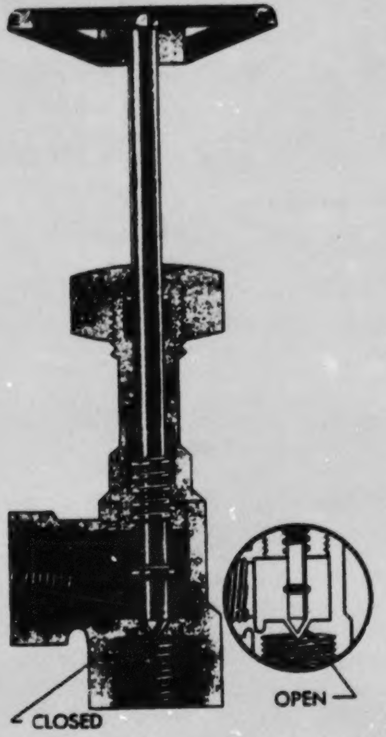

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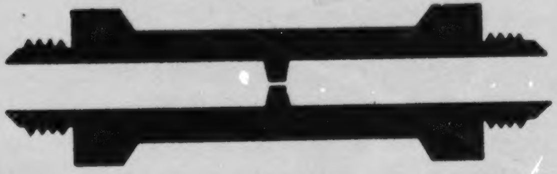
Figure 9-8.—Cross-sectional view of a needle valve.



FP.152

Figure 9-9.—Fixed restrictor.

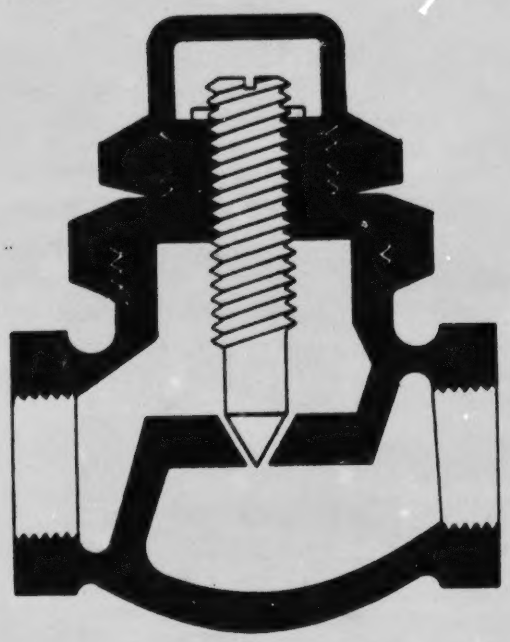


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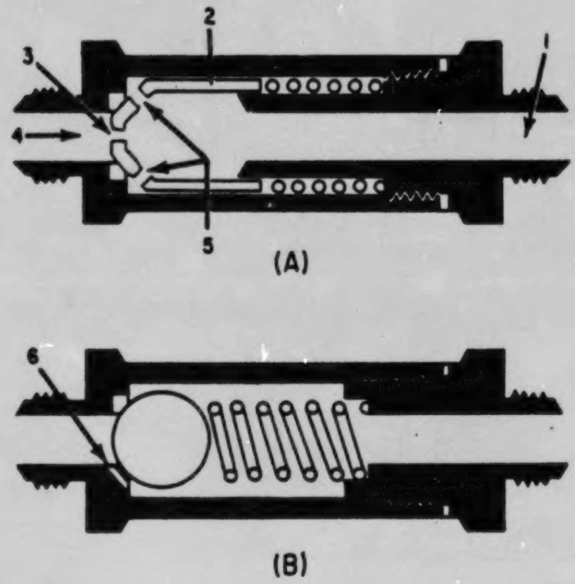
Figure 9-10.—Variable restrictor.

normal speed of operation in one direction and limited speed of operation in the other. Since this type valve allows normal flow in one direction and restricted flow in the other, it is often referred to as a one-way restrictor. Some typical examples of orifice check valves are illustrated in figure 9-11.

Figure 9-11 (A) illustrates a cone-type orifice check valve. When sufficient fluid pressure is applied at port (4), it overcomes spring tension and moves the cone (2) off its seat. The two orifices (5) in the illustration represent several openings located around the slanted circumference of the cone. These orifices allow free flow of fluid through the valve while the cone is off its seat. When fluid pressure is applied through port (1), the force of the fluid and spring tension move the cone to the left and on its seat. This action blocks the flow of fluid through the valve, except through the orifice (3) in the center of the cone. Thus, the size of orifice (3) determines the rate of flow through the valve as the fluid flows from right to left.

Figure 9-11 (B) shows a ball type orifice check valve. Fluid flow through the valve from left to right forces the ball off its seat and allows normal flow. Fluid flow through the valve in the opposite direction forces the ball on its seat. Thus, the flow is restricted by the size of the orifice (6) located in the housing of the valve.

In some fluid power systems it is necessary that the actuating device (for example, an actuating cylinder) move slower in one direction than the other. In some systems an orifice check valve is used to accomplish this requirement. The valve is installed in the alternating line that carries the fluid from the actuating device as it is actuated in the direction in which slower movement is desired. (The



FP.154

1. Outlet port.
2. Cone.
3. Orifice.
4. Inlet port.
5. Orifices.
6. Orifice.

Figure 9-11.—Orifice check valves.

line which delivers fluid under pressure to the actuating device for one direction of operation becomes the line which carries the return flow from the actuating device during the opposite direction of operation; hence, the term alternating line.) This causes the speed of the actuating device to be retarded, since the fluid cannot escape from the actuating device any faster than the orifice will allow fluid to flow to return. When the device is operated in the opposite direction, the alternating line containing the orifice check delivers fluid under pressure to the actuating device. Flow in this direction is unrestricted through the valve.

NOTE: The direction of free flow through the orifice check valve is indicated by an arrow stamped on the housing.

This type installation is sometimes used in aircraft hydraulic systems. It is used in the subsystem that retracts and extends the landing gear. The orifice check valve is installed in the UP line (pressure line for the retraction of the landing gear) in such a manner that it permits free flow when the landing gear is retracted. This allows for rapid retraction of the landing gear. When the gear is extended, fluid leaving the cylinder returns through the UP line and must pass through the orifice of the valve. Thus, a cushioning effect results and the gear falls slowly, thereby preventing structural damage. If the restriction were placed in the DOWN line, it would limit the quantity of fluid entering the cylinder, but would have no effect on the fluid leaving. This would not satisfy the situation because the heavy gear tends to fall freely, causing a partial vacuum in the cylinder. Thus, the gear would fall too rapidly, resulting in structural damage to the aircraft.

Circuits in which the flow is restricted as the fluid leaves the actuating device, such as the landing gear circuit just described, are commonly referred to as meter-out circuits. That is, the fluid is metered out of the actuating device. Some circuits require the flow of fluid to be restricted as it enters the actuating device. These circuits are referred to as meter-in circuits.

A meter-in circuit, utilizing an orifice check valve, is sometimes used to control the sequence of operation in one direction of two or more actuating devices in a subsystem. A subsystem of this type is illustrated in figure 9-12. In this system the sequence of operation is controlled during the extension of the piston rods. Notice that the directional control valve is positioned to deliver system pressure to the right-hand end of each cylinder which will extend the piston rods. Since the line to cylinder (1) contains the orifice check valve, the flow is restricted to the cylinder; therefore, the fluid takes the path of least resistance and flows to cylinder (2). After the piston rod of cylinder (2) is fully extended, the restricted flow of fluid through the orifice check valve will eventually extend the piston rod of cylinder (1).

During the retraction stroke of the piston rods, the fluid flows in the opposite direction in the alternating lines. Since this allows free flow of return fluid through the orifice check valve, the rods will retract at approximately the same time. It should be noted that if the orifice check valve was replaced with a fixed or variable restrictor, the sequence of operation could be controlled in both directions.

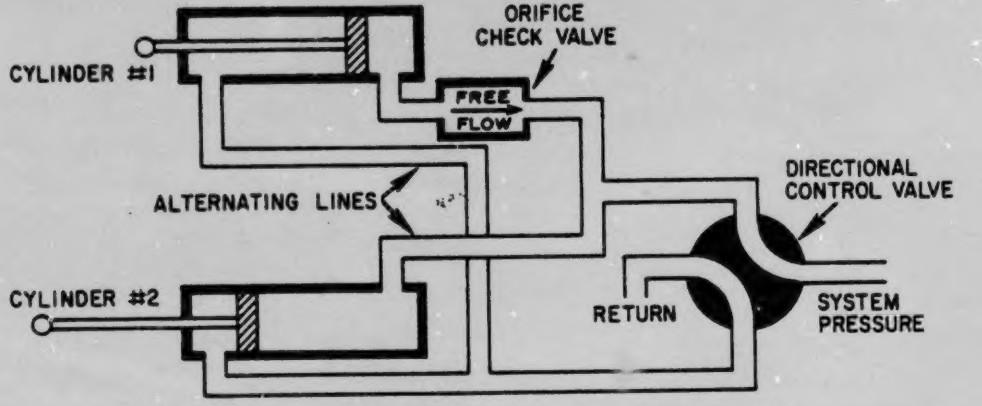


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Figure 9-12.—Meter-in circuit containing orifice check valve.

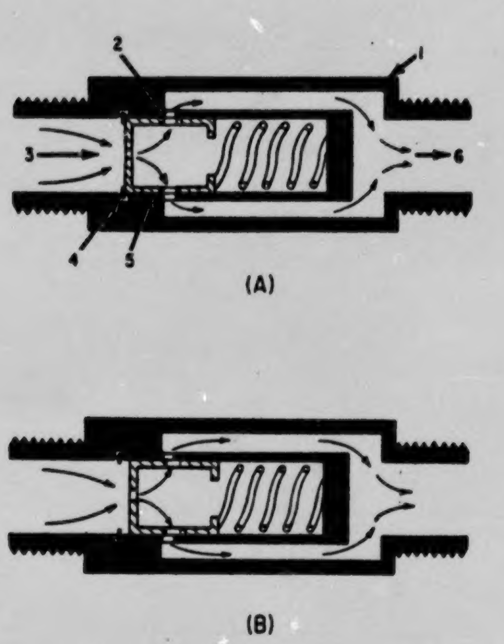
COMPENSATED VALVES

The flow control valves previously discussed in this chapter are not compensated for changes in fluid temperature or pressure and, therefore, are sometimes referred to as noncompensating valves. The rate of flow through these valves can vary at a fixed setting if either the pressure or temperature of the fluid changes. Changes in viscosity (discussed in chapter 2), which are often the result of temperature changes, can also cause flow variation through a valve. The valves previously described are satisfactory for use in fluid power systems in which slight variations of flow are not a critical factor to be considered. However, some systems require extremely accurate control of the actuating device. Compensated flow control valves are frequently used for this purpose. They automatically change the valve adjustment to compensate for pressure changes encountered in the system, thereby providing a constant flow at a given setting.

Figure 9-13 illustrates an example of a compensated flow control valve. This type valve meters a constant flow regardless of variations in system pressure. Although it is usually used to meter fluid into a circuit, it can also be used to meter fluid as it leaves the circuit. Flow control, flow regulator, and constant flow valve are all terms used to describe this valve. In this manual it is referred to as a flow regulator.

This flow regulator has only one moving part, the piston (5), as illustrated in figure 9-13. This valve will regulate flow from left to right only. Although the flow from right to left is restricted to the size of the orifice in the head of piston (5), the flow is not regulated in this direction. The body of the valve is marked with an arrow to indicate the direction of regulated flow.

Operation of the flow regulator can be seen in figure 9-13. View (A) shows the fluid flowing through the valve in the direction of regulated flow; however, in this position the valve allows free flow (relative to the size of the orifice in the head of piston (5)). Fluid enters port (3), passes through the orifice in the head of piston (5), through the slots (2) in the side of the piston (5), and out port (6). If the flow entering port (3) increases to a velocity greater than the capacity of the orifice in the head of piston (5), the resistance increases. This increase in resistance results in a pressure differential between the fluid entering the orifice and the fluid leaving it. This pressure differential, caused by a momentary increase in flow, overcomes spring tension and moves the piston (5) to the right. As the piston moves to the right, the openings at slots (2) in the piston and regulator body decrease in size (fig. 9-13(B)), and an additional restriction is placed on the fluid which decreases the rate of flow. The piston cannot move to the right far enough to completely block the slots in the



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1. Body.
2. Slots.
3. Input port.
4. Retainer.
5. Piston.
6. Output port.

Figure 9-13.—Flow regulator.

side of the regulator body. Although the pressure on the right side of the piston will build up to a value equal to the pressure in port (3) and against the left side of the piston, spring tension will overcome this equalization of pressures and will prevent a complete blockage of flow.

An increase of pressure normally increases fluid flow through an orifice, but this is not the case with the flow regulator. As the pressure increases, the size of the orifices (slots) decreases, thus maintaining a constant flow. If the resistance to movement of the actuating device decreases, the fluid flow starts to increase. This increase of flow to the actuating device causes a decrease in pressure on the right side of piston (5). This allows the piston to move to the right and thereby decreases the size of the slot openings (2). This allows less fluid to flow to the actuating device. Thus, the flow regulator maintains a constant rate of flow regardless of variations in system pressure and regardless of the resistance to movement of the actuating device.

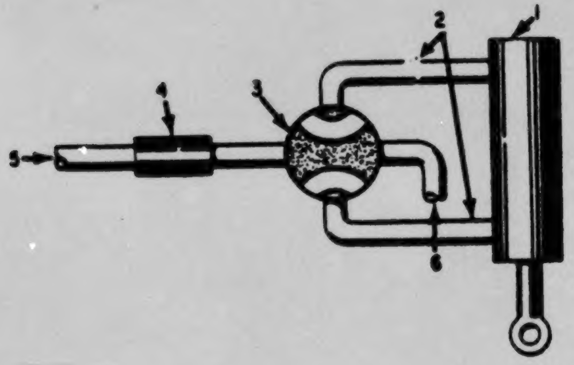
An example of a typical flow regulator installation is shown in figure 9-14. This installation provides for the fluid to be metered into the circuit. System pressure enters port (5). When the directional control valve (3) is positioned, fluid flows through the flow regulator (4). Thus, regardless of the direction of movement of the actuating cylinder (1), one of the alternating lines (2) will have regulated flow through it, insuring a smooth operation of the actuator.

Flow regulators are available in different flow capacities, and are usually rated in gallons per minute (gpm). The type of valve discussed in this section is nonadjustable. Adjustable compensated valves are required and are available for some fluid power systems.

FLOW EQUALIZER

Flow equalizers, sometimes referred to as flow dividers, are used in some hydraulic systems to synchronize the operation of two actuating units. To accomplish this, the flow equalizer divides a single stream of fluid from the directional control valve into two equal streams. Thus, each actuating unit receives the same rate of flow, and both move in unison. During operation in the opposite direction, the flow equalizer combines the two streams of fluid at an equal rate. Therefore, the flow equalizer synchronizes the movement of the actuating units during both directions of operation. Since this valve provides synchronized flow in both directions, it is said to be dual acting.

One type of flow equalizer is illustrated in figure 9-15. View (A) shows the valve in the splitting (divided flow) position. Fluid under pressure from the directional control valve enters port (3). The fluid pressure overcomes spring tension, forces the plug (4) down, and uncovers the two orifices in the sleeve (2). The fluid then splits and tends to flow equally through the two side passages (1) and (5). The fluid pressure overcomes spring tension and



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1. Actuating cylinder.
2. Alternating lines.
3. Directional control valve.
4. Flow regulator.
5. Pressure line.
6. Return line.

Figure 9-14.—Flow regulator installation.

opens the two splitting check valves (7) and (15). Then the fluid flows through these splitting check valves, through the metering grooves (10) and (14), through ports (9) and (13), and through connecting lines to the actuating units. Any difference in the rate of flow between the two passages results in a pressure differential between the two passages. Then the free-floating metering piston (11) shifts to equalize the internal pressure, and the flow equalizes.

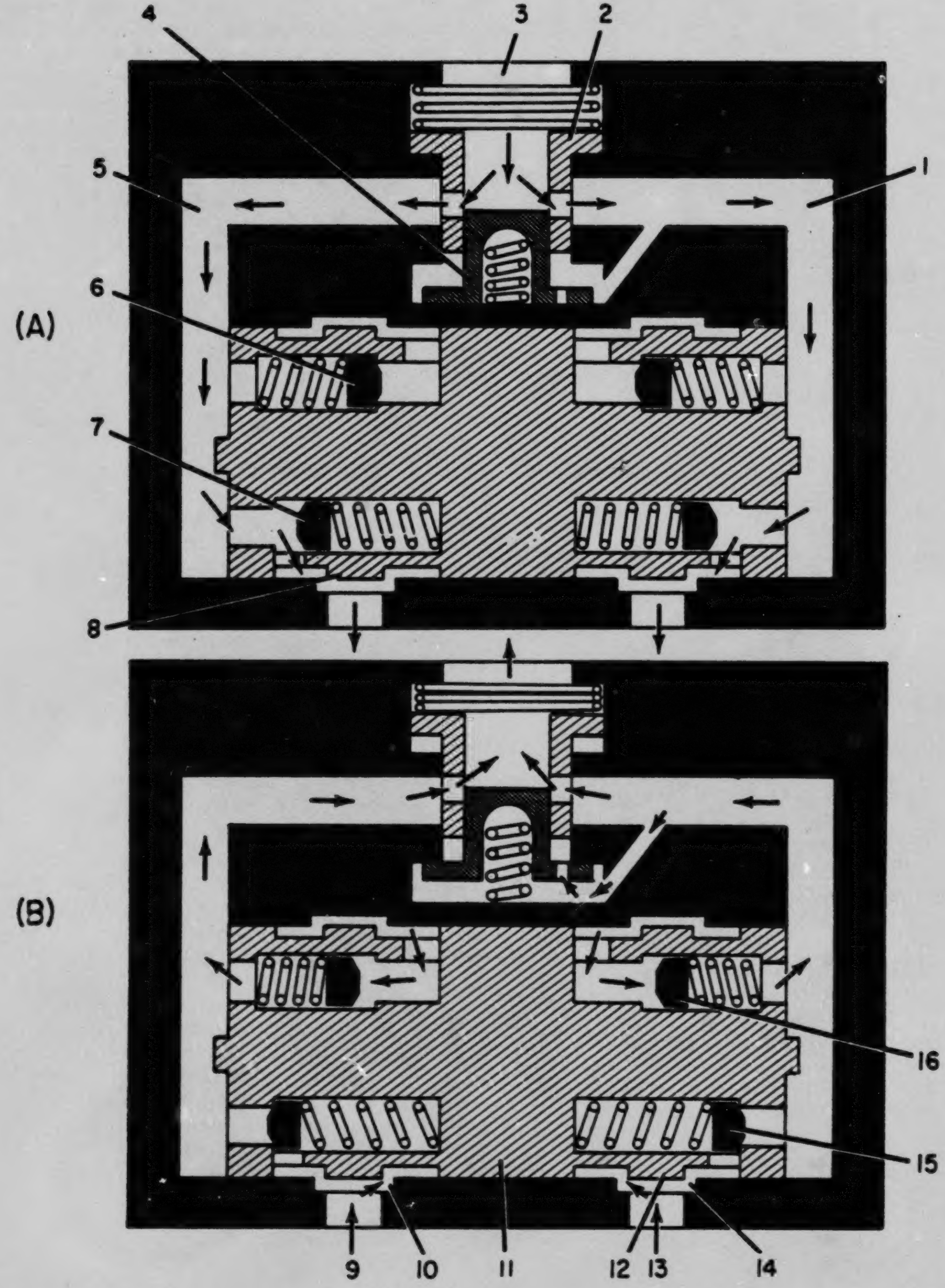
To illustrate this equalization action, assume that the actuating unit attached to a line from port (9) meets less resistance than the one attached to a line from port (13). As a result, the rate of flow through port (9) tends to increase, but in so doing, the rate of flow also increases through passage (5). Since the fluid leaving port (13) meets with more resistance, the flow through passage (1) decreases, and the pressure becomes greater than the pressure in passage (5). This momentary pressure differential forces the free-floating metering piston (11) to the left. This causes the space between the piston land (8) and the metering groove (10) to become smaller, which restricts the flow of fluid out of port (9). Thus, the flow equalizer imposes a restriction on the fluid that has a tendency to increase in rate of flow, and the two streams equalize.

The combining position of the flow equalizer is illustrated in figure 9-15 (B). This shows the valve joining the two streams of fluid as it flows from the actuating units. In this position, the fluid enters ports (9) and (13) of the valve. The fluid cannot return through the splitting check valves. Therefore, it takes the path of least resistance, which is around the cylindrical shaped metering piston, and enters the combining check valves (6) and (16) as indicated by arrows. The pressure of the fluid overcomes spring tension, opens the check valves, and then the fluid flows through passages (1) and (5) to the orifice sleeve (2). The fluid pressure will then force the orifice sleeve upward, which opens the orifices and allows the fluid to flow out port (3).

Again for purposes of illustration, assume that the actuating unit attached to a line from port (9) moves with less resistance than the unit attached to a line from port (13). The rate of flow into port (9) tends to increase, but as the fluid leaves the combining check valve (6) and flows through passage (5) it is restricted by the orifice. Therefore, if the flow momentarily increases, the restriction of flow through the orifice will cause an increase in pressure in passage (5). This differential in pressure between passages (5) and (1) will force the metering piston (11) to the right. This results in a restriction between the metering groove (10) and the piston land (8). Thus, the stream of fluid which tends to flow at a greater rate is restricted and equalizes with the other stream.

PRIORITY VALVES

In systems with two or more circuits, it is sometimes necessary to have some means of supplying all available fluid to one particular circuit in case of a pressure drop in the system. A priority valve is often incorporated in the system to insure a supply of fluid to the critical circuit. The components of the system are arranged so that the fluid to operate each circuit, except the one critical circuit, must flow through the priority valve. A priority valve may also be used within a subsystem containing two or more actuating units to insure a supply of fluid to one of the actuating units. In this case the priority valve is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2
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1
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(A)
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(B)
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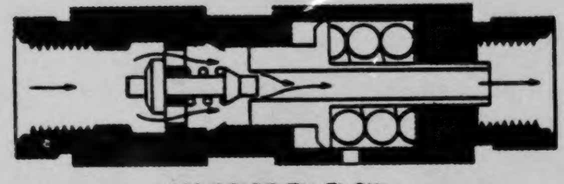
FP.158

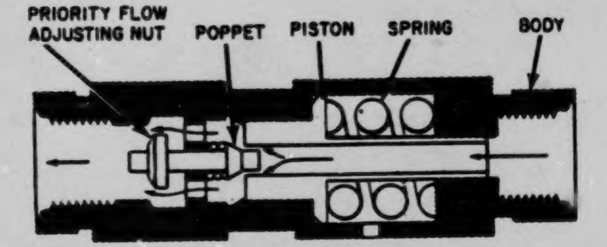
Figure 9-15.—Flow equalizer.

Nomenclature for figure 9-15.

1. Side passage.
2. Sleeve.
3. Port.
4. Plug.
5. Side passage.
6. Combining check valve.
7. Splitting check valve.
8. Piston land.
9. Port.
10. Metering groove.
11. Free-floating metering piston.
12. Piston land.
13. Port.
14. Metering groove.
15. Splitting check valve.
16. Combining check valve.



(A) PRIORITY FLOW



(B) FREE FLOW

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Figure 9-16.—Priority valve.

incorporated in the subsystem in such a location that the fluid to each actuating unit, except the critical unit, must flow through the valve.

One type of priority valve is illustrated in figure 9-16. View (A) shows the valve in the priority flow position; that is, the fluid must flow through the valve in the direction indicated by the arrows to get to the noncritical circuits or actuating units. With no fluid pressure in the valve, spring tension forces the piston against the stop and the poppet seats against the hole in the center of the piston. As fluid pressure increases, the spring compresses and the piston moves to the right. The poppet follows the piston, sealing the hole in the center of the piston, until the preset pressure is reached. (The preset pressure depends on the requirements of the system and is set by the manufacturer.) Assume that the critical circuit or actuating unit requires 1,500 psi. When the pressure in the valve reaches 1,500 psi, the poppet reaches the end of its travel. As the pressure increases, the piston continues to move to the right, which unseats the poppet and allows flow through the valve, as indicated in figure 9-16 (A). If the pressure drops below 1,500 psi, the compressed spring forces the piston to the left, the poppet seats, and flow through the valve stops.

Figure 9-16 (B) shows the priority valve in the free flow position. The flow of fluid moves the poppet to the left, the poppet spring compresses, and the poppet unseats. This allows free flow of fluid through the valve.

FLOWMETERS

Although flowmeters are normally associated with systems in which fluids are consumed, such as oil, gasoline, water, etc., they are sometimes required in fluid power systems. One of the most important uses of flowmeters in fluid power systems is in test stands which are used to test and adjust fluid power systems and/or components. For example, pumps, which are rated in gallons per minute (chapter 8), can be tested for their rated capacity by the use of a test stand with a flowmeter incorporated.

Measurement of flow may be expressed in units of rate, such as gallons per minute, pounds per hour, cubic feet per second, or in terms of total quantity, such as gallons, pounds, or cubic feet. (This is similar to the speedometer of an automobile. The needle indicates the speed of the automobile in miles per hour, which compares to the rate-of-flow type flowmeter.

The other indicator, called the odometer, indicates total miles and compares to the quantity type flowmeter.)

A reciprocating pump that displaces a uniform volume of fluid for each stroke of its piston could be used as a meter by installing a device for counting the piston strokes. However, the pump would have to be designed to minimize leakage and to guarantee uniform displacement. Measurement of flow is accomplished by a variety of means, depending upon the quantities, flow rates, and types of fluid involved. Fluid meters are designed to measure fluids of definite specific gravities and characteristics, and must be used only for the purpose and the fluid for which they were designed. Each meter is tested and calibrated before it is shipped from the factory and must be tested and calibrated at periodic intervals throughout its service life. Several types of flowmeters are described in the following paragraphs.

NUTATING PISTON DISC FLOWMETER

In this type flowmeter the fluid passes through a fixed volume measuring chamber divided into upper and lower compartments by a disc. During operation, one or the other compartment is continually being filled while the other is being emptied. As it passes through these compartments, the force of the fluid causes the disc to roll around in the chamber, in a manner described later. This movement of the disc operates a counter, through suitable gearing, to indicate the volume of fluid passed through the meter. The counter somewhat resembles the odometer of an automobile, previously mentioned, except that this type flowmeter is usually designed to register gallons.

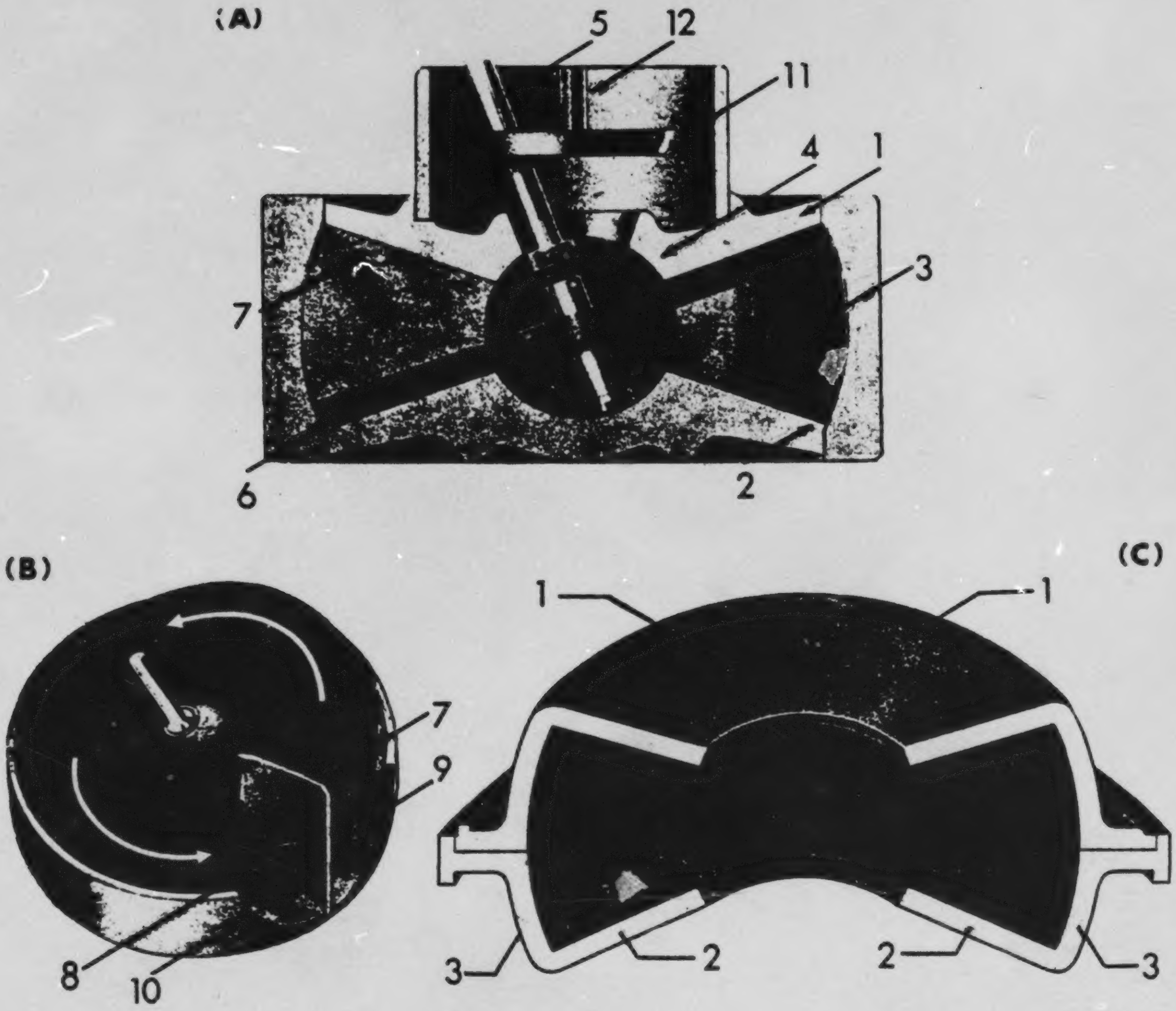
The heart of the meter is the measuring chamber and the disc piston. Views (A) and (B) of figure 9-17 show how the disc is located in the measuring chamber. View (C) of figure 9-17 is a sectional view illustrating one-half of the measuring chamber. The chamber is bound at the top and bottom by conical surfaces (1) and (2), which are joined at their outer edges by spherical surface (3). A sectional view of the entire meter is illustrated in figure 9-18.

Referring to figures 9-17 (A) and (B), the upper and lower surfaces of the chamber converge towards the center to form a spherical cavity for the ball (4). The spindle (5) passes through the ball and is connected to the counting gears (fig. 9-18). Disc (6) is attached to the ball. Both the ball and disc are machined to fit closely in the chamber. There is a slot (8) in the disc at one point, through which passes the thin partition (7). This partition divides the chamber into two equal parts. There are openings in the outer wall of the chamber on each side of the partition. Opening (9) is the fluid inlet, while opening (10) is the outlet.

When the ball carrying the disc and the spindle is tilted as far as possible, the bottom of the disc makes a close contact with the bottom conical surface of the chamber, while the top of the disc similarly contacts the upper conical surface at the opposite end of the disc. Since the disc is flat, while the contacting surfaces are conical, contact takes place along a straight line on each surface. The lines of contact produce seals, which, when taken in connection with the partition (7), divide both the upper and lower compartments into two parts. The net effect is that the disc and partition produce four separate compartments in the measuring chamber, two above the disc and two below. The top and bottom compartments are separated from each other by the disc, while the pairs of compartments respectively above and below the disc are separated by the seal formed at the line of contact between the disc and the conical top and bottom surfaces, and also by the partitions.

Spindle (5) extends from ball (4) and passes through wheel (11) at a point near its outside edge. The vertical shaft (12) is attached to wheel (11) and rotates with it. This shaft is connected at its upper end to the measuring gears, and is mounted directly over ball (4). When the wheel (11) turns on its axis, the position of the shaft keeps the spindle inclined at just the angle to produce a continuous seal between disc (6) and the upper and lower surfaces of the measuring chambers.

For the purpose of simplicity, consider the meter as a pump driven by some outside force. The action of the meter can be understood by imagining wheel (11) to be revolved by means of shaft (12). The spindle (5) would revolve with the wheel and shaft, and would trace a conical path, as shown in figure 9-19. This movement of the spindle would control the positioning of the disc. When the spindle is in position (A) (fig. 9-19), for example, the disc



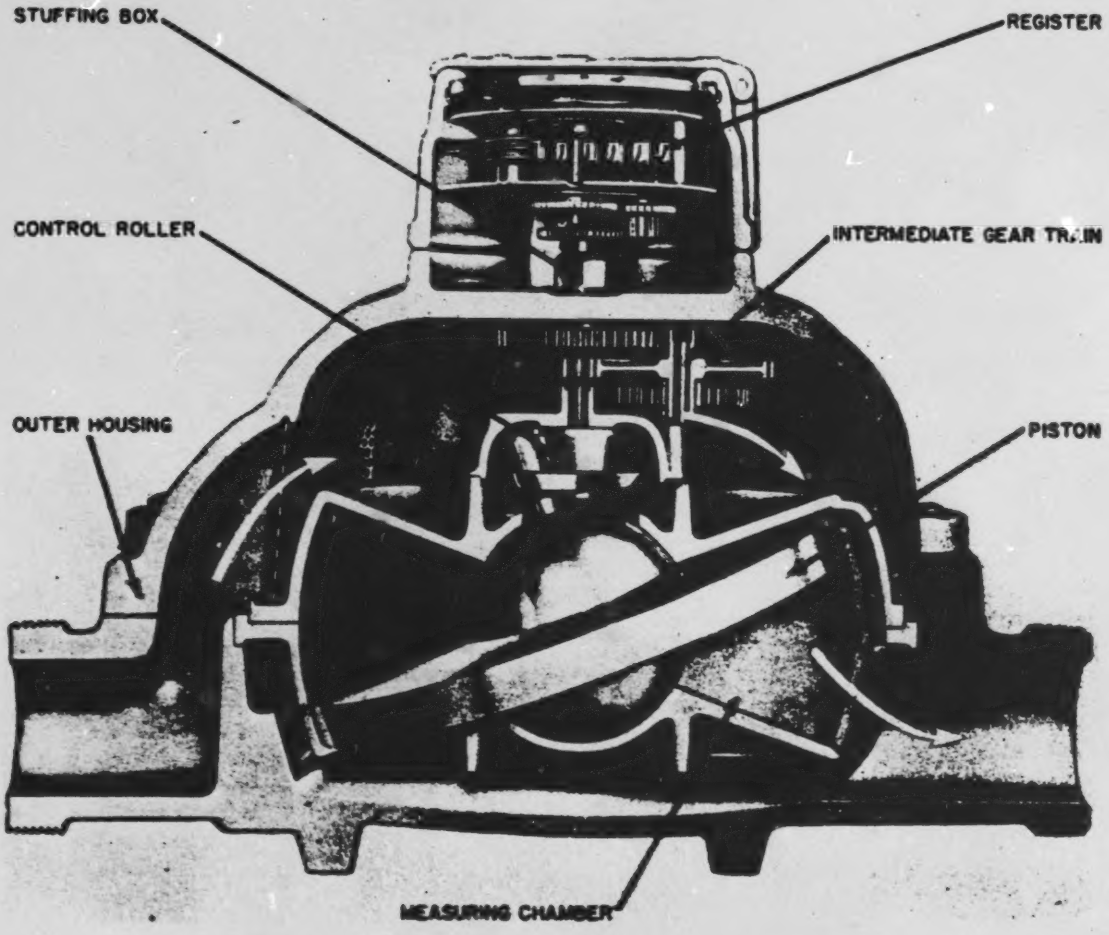
FP.160

1. Measuring chamber (top surface).
2. Measuring chamber (bottom surface).
3. Measuring chamber (outer edge).
4. Ball.
5. Spindle.
6. Disc.
7. Chamber partition.
8. Slot.
9. Inlet opening.
10. Outlet opening.
11. Wheel.
12. Shaft.

Figure 9-17.—Nutating piston disc flowmeter (sectional views).

would also be in position (A), while the positions (B) and (C) for the spindle and disc would also correspond.

The disc cannot rotate, because partition (7) stands in slot (8). The disc, therefore, wobbles up and down (nutates), while the seal lines, formed by the disc and the top and bottom walls of the measuring chamber, are made to revolve around the chamber.

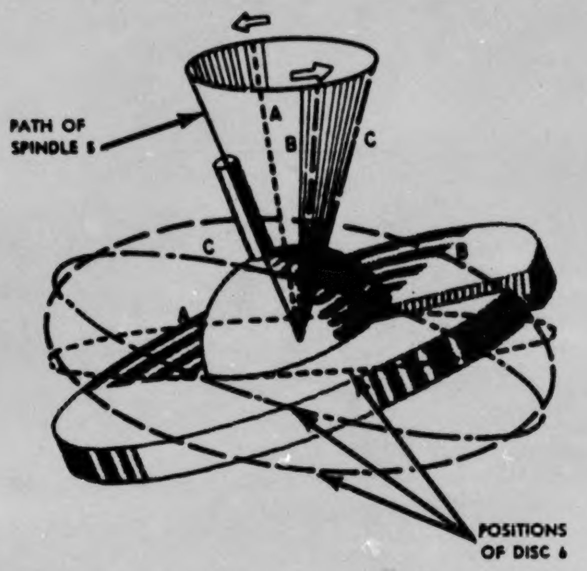


FP.161

Figure 9-18.—Nutating piston disc flowmeter (indicating fluid flow).

Again for simplicity, consider only the lower partition of the chamber. The seal will always be along the line which has the greatest inclination. As the seal line moves in the direction shown by the arrows in figure 9-18, it will sweep the fluid before it and cause the fluid to be discharged through the opening (10). At the same time, the compartment behind the moving line of the seal will be increasing in size. Since the space is open to the inlet (9), it is filled with fluid. When the line of seal passes the partition (7), all the fluid formerly in front of the seal will have been forced out of the discharge port. The seal line then starts to push the fluid, which was formerly behind it, forward. The line of flow of the fluid is as shown in figure 9-18.

Obviously, if the wheel (11) were continuously rotated, the disc (6) would move a volume of fluid equal to the volume of the lower half of the chamber from the inlet to the outlet, for every rotation. During this same revolution, the top section is doing the same, except its seal is always directly opposite the lower seal in the measuring chamber. Therefore, for every revolution, the piston will displace the volume of the entire chamber just once.



FP.162

Figure 9-19.—Operation of disc and spindle of nutating piston disc flowmeter.

In the previous discussion, the meter is described as though it were a pump operated by the rotation of the wheel (11). Actually the operation of the meter is just the reverse. It is operated by the slightly greater fluid pressure at the inlet as compared with the outlet. This pressure differential causes the seal line to advance around the measuring chamber, and in doing so, it revolves the wheel (11). This in turn revolves the indicating register of the meter by means of shaft (12) and suitable reduction gears.

Standard meters of this type are suitable for temperatures up to 200°F, and for pressures to 150 psi, although models are available for higher temperatures and pressures. The meters are accurate to about 1 percent or less. The accuracy of the meter is not affected by pressure variations.

PROPELLER TYPE FLOWMETER

Figure 9-20 illustrates a propeller type flowmeter. The propeller is located in the line of flow and is connected by suitable gearing to the indicator or counter. The propeller rotates at a speed relative to the velocity of the flow through the line. The revolutions of the propeller are registered through the gearing to the counter, the rate of rotation being volume rate of flow. This type meter is calibrated by the manufacturer for a specific fluid. The accuracy of this meter depends, to varying degrees, on the temperature, pressure, and characteristics of the fluid.

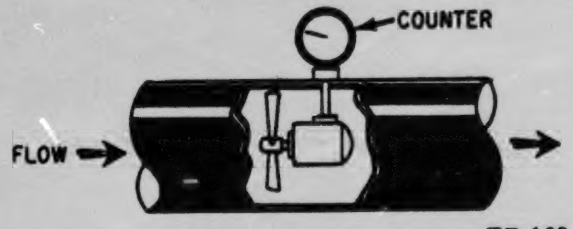


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Figure 9-20.—Propeller type flowmeter.

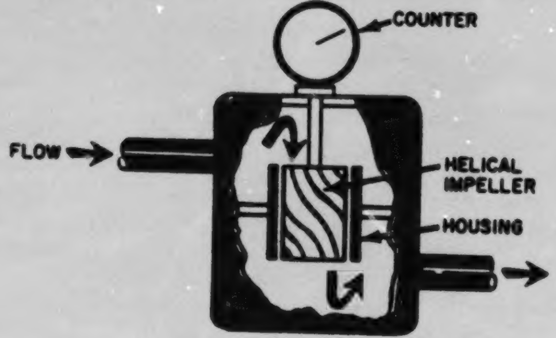
TURBINE TYPE FLOWMETER

The turbine type flowmeter is similar to the propeller type just described. Figure 9-21 illustrates an installation of a turbine type flowmeter. The fluid flows through the helical (spiral) impeller. This flow causes the impeller to rotate. The impeller is connected through suitable gearing to the counter. The revolutions of the propeller, which change as the velocity of the flow changes, are counted through the gearing to the counter. The rate of rotation of the impeller indicates the volume flow rate. Like the propeller type flowmeter, the accuracy of the turbine type depends on the temperature, pressure, and characteristics of the fluid. This type flowmeter is calibrated by the manufacturer for a specific type fluid.

ROTAMETER

The rotameter is a device for measuring the rate of flow of a fluid. Figure 9-22 illustrates the operation of a rotameter.

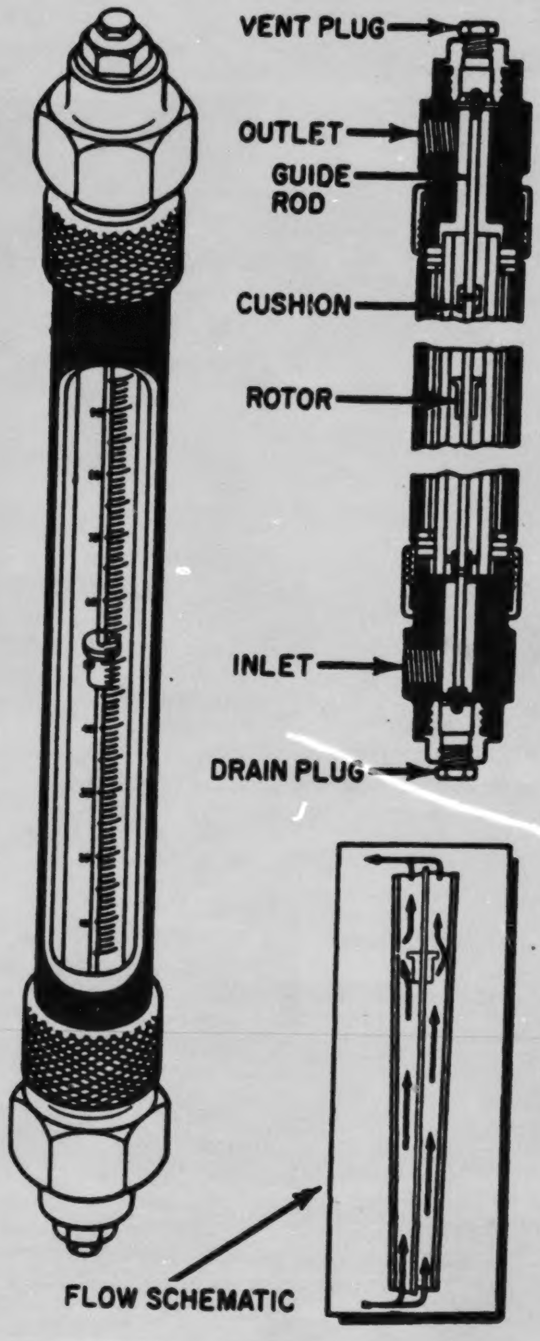
The rotameter is an upright glass tube through which the fluid flows. A metal casing with a Plexiglas window protects the glass tube. The tube is tapered, with the small end at the bottom. Inside, a small metal rotor with a central hole slides up and down on a guide


COUNTER
FLOW
HELICAL IMPELLER
HOUSING

FP.164

Figure 9-21.—Turbine type flowmeter.

rod. Small vanes cut in the sides of the rotor cause it to spin as it slides freely up and down in the tube. Since the tube is tapered, the space between the rotor and the tube wall increases as the rotor rises, permitting more fluid to pass through that space. Therefore, the rotor always rises to a height corresponding to the rate of flow at any particular time. A scale on the tube is calibrated to indicate the rate of flow in the desired measurement—gallons per hour, gallons per minute, pounds per hour, etc.


VENT PLUG
OUTLET
GUIDE ROD
CUSHION
ROTOR
INLET
DRAIN PLUG
FLOW SCHEMATIC

FP.165

Figure 9-22.—Rotameter.

CHAPTER 10

MEASUREMENT AND CONTROL OF PRESSURE

For safe and efficient operation, most fluid power systems are designed to operate at a specific pressure or, at least within a close range of a specific pressure. Therefore, most fluid power systems are provided with a means for measuring and indicating the pressure in the system. Likewise, a means must be provided for controlling this pressure. Various types of pressure gages are used to measure and indicate the pressures in fluid power systems and various types of valves, pressure regulators, pressure switches, or similar mechanisms are used to control these pressures.

The operation and applications of various types of pressure gages used in fluid power systems are discussed in the first part of this chapter. The latter part of the chapter is devoted to the valves and other mechanisms commonly used in controlling pressure.

PRESSURE GAGES

Pressure gages are used in fluid power systems to measure and indicate pressure so that the operator of fluid power equipment can maintain pressure at safe and efficient operating levels. Any excess or deficiency of pressure should be immediately investigated with a view of locating and removing the cause of the trouble.

Pressure is generally measured in pounds per square inch, as discussed in chapter 2. Gages used in fluid power systems are therefore calibrated in pounds per square inch (psi). Gage readings indicate the fluid pressure set up by the opposition of forces within the system. Atmospheric pressure also acts on the system, but it can be ignored in practical operation because its action at one place is balanced by its equal and opposite action at another place. When it is taken into account in scientific calculations, the pressure of a system is referred to as absolute pressure (psia). In this manual, however, system pressure is referred to as gage pressure (psig). (Absolute and gage pressures are defined in chapter 2.)

Most pressure gages used in fluid power systems are of the direct reading type; that is, both the measuring and the indicating mechanisms are contained in one housing and the complete unit is connected directly into the system or to a line leading from the system. Some fluid power systems are equipped with electrically operated (synchro) pressure indicators. In this type, pressure transmitters are incorporated in the system at required locations. The transmitter operates similar to the measuring mechanism of the direct reading gage; however, movement of the transmitter resulting from changes in pressure is relayed by mechanical and electrical means to a pressure indicator which can be mounted in a convenient location for the operator. Several transmitters may be used in a system. Each transmitter may be connected to separate pressure indicators or several transmitters may be connected through a selector switch to one indicator. The operator can then select pressure readings from any one of the transmitters.

BOURDON TUBE GAGES

The most common type of pressure gage used in fluid power systems is the Bourdon spring gage. The name of the gage comes from its inventor, a French engineer, Eugene Bourdon. The Bourdon tube, a C-shaped element, is the heart of the gage. There are variations of the C-shaped tube used in the construction of pressure gages. The most common of these are the spiral and the helical shaped tubes.

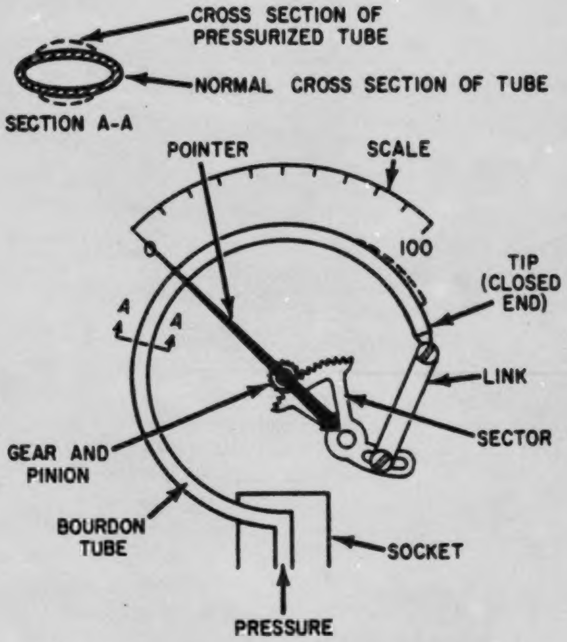
These three types of Bourdon tube gages—C-shaped, spiral, and helical—are described in the following paragraphs.

C-Shaped Tube

A simple Bourdon tube pressure gage consists of a Bourdon tube, a gear-and-pinion mechanism, a dial, and a pointer. These essential parts of a Bourdon tube gage are illustrated in figure 10-1. The curved hollow Bourdon tube (C-shaped) is closed at one end and is connected to the fluid pressure at the other end. When pressure is applied the tube tends to straighten out, like a garden hose when the water is first turned on. Pressure acts equally on every square inch of area inside of the tube; but, since the surface area on the outside inner surface of the curve is greater than the surface area on the shorter radius, the force acting on the outer surface is greater than the force acting on the inner surface. When the pressure is applied the tube straightens out until the force of the fluid pressure is balanced by the elastic resistance of the material composing the tube. Since the open end of the tube is anchored in a fixed position, changes in pressure move the tip (closed end). Through suitable linkage and a gear-and-pinion mechanism, this tip movement is used to rotate the indicator pointer around a graduated scale. The scale (dial) is properly calibrated so that the needle points to the number which corresponds to the exact pressure. The tube performs in the same manner as a spring. When the pressure is removed, it returns to its original position, and the pointer indicates zero pressure.

The internal working mechanism of the Bourdon tube gage is housed in a gage case. Gage cases are made of plastic, corrosion-resistant metal, or a combination of these materials. The case assembly serves to protect the working parts of the gage from mechanical damage, dirt, sand, and, in some designs, from moisture. Secondarily, it may serve as a means of mounting the gage on an instrument panel, wall, or piece of equipment.

Simplex, vacuum, compound, hydraulic, differential, duplex, electric alarm, and depth are all types of Bourdon tube gages containing the C-shaped tube. A few of the more pertinent of these used in fluid power systems are discussed in the following paragraphs.



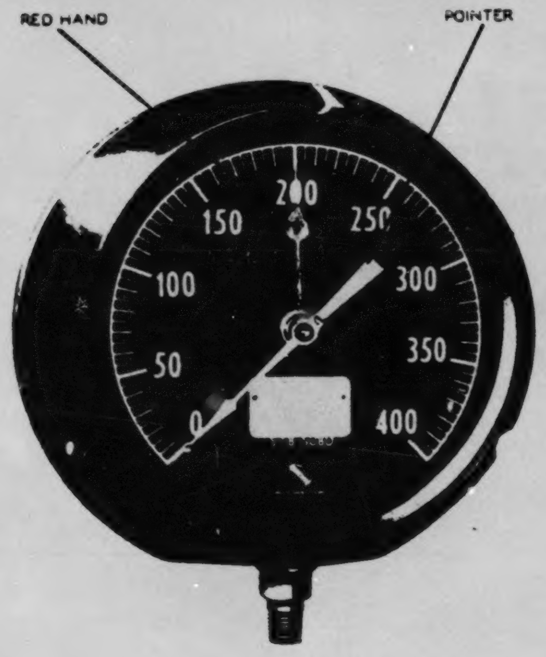
FP.166

Figure 10-1.—Essential parts of Bourdon tube pressure gage.

SIMPLEX.—A simplex Bourdon tube pressure gage is illustrated in figure 10-2. One pointer (hand) is connected to the gear shaft which extends through the dial face. This pointer indicates the pressure of the system. The other pointer, normally painted red, pivots on the gear shaft and is manually positioned. It is set to the normal working pressure of the system to which the gage is connected. On some gages, red lines are painted on the dial to indicate the minimum and the maximum pressures that should be carried in the system to which the gage is attached. These lines should be properly labeled.

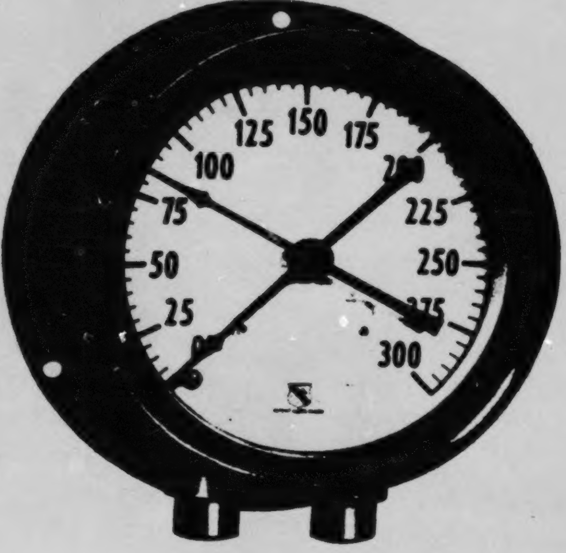
A simplex Bourdon tube gage may be used for measuring the pressure of steam, air, water, oil, and similar liquids or gases.

DUPLEX GAGES.—A duplex Bourdon tube gage has two separate tube mechanisms within the same case, each acting independently of the other. A pointer is connected to the gear mechanism of each tube, and each pointer


RED HAND
POINTER
0
50
100
150
200
250
300
350
400

FP.167

Figure 10-2.—Simplex Bourdon tube pressure gage.


25
50
75
100
125
150
175
200
225
250
275
300

FP.168

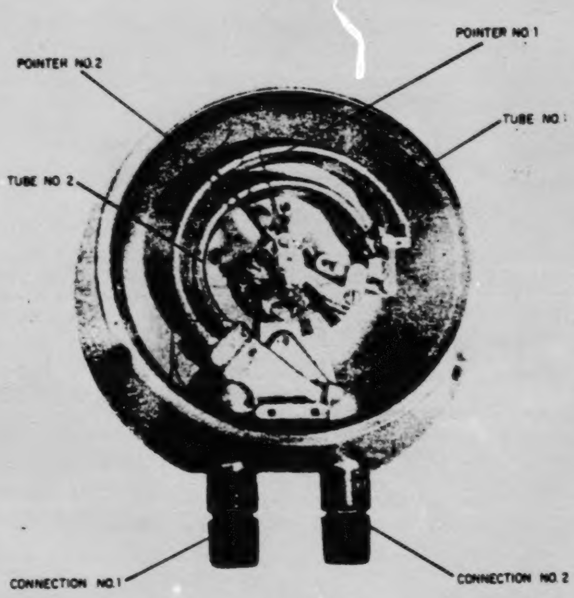
Figure 10-3.—Duplex Bourdon tube gage.

moves over the face of the dial without interfering with the other pointer. (See fig. 10-3.)

One pointer on the face of the gage illustrated in figure 10-3 points to 0, indicating that there is no pressure in the line to which the respective Bourdon tube is attached. The other pointer of the gage, however, indicates that a pressure of 85 psi is being exerted on the tube to which it is attached.

Figure 10-4 shows a duplex Bourdon tube gage with the face removed. Note the position of the pointers, and also the separate connections to the different pressure sources at the base of the case.

Duplex Bourdon tube gages are used for such purposes as showing the pressure drop between the inlet and the outlet side of a strainer. The reading of each pointer indicates whether the strainer is clean or dirty; that is, if the pressure is much greater on the inlet side of the strainer, it indicates that foreign matter on the strainer is very likely responsible for the

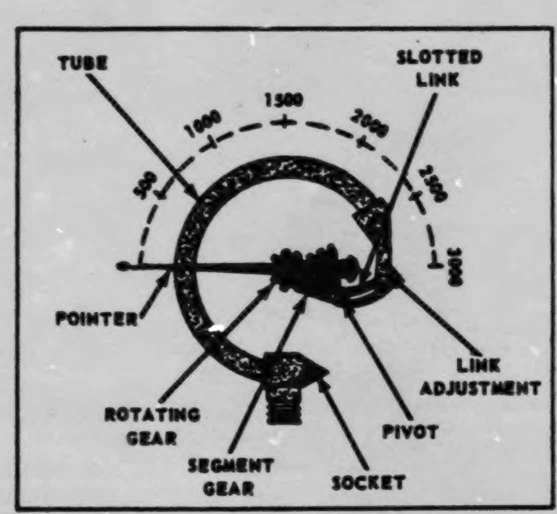

POINTER NO 1
POINTER NO 2
TUBE NO 1
TUBE NO 2
CONNECTION NO 1
CONNECTION NO 2

FP.169

Figure 10-4.—Mechanism of duplex Bourdon tube gage.

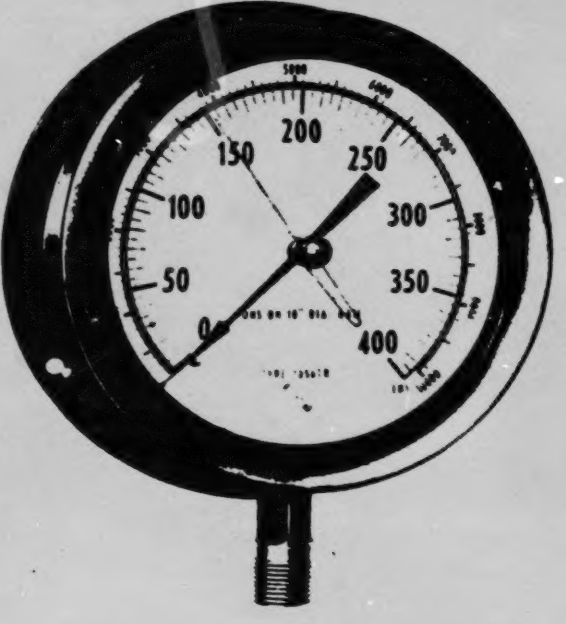
higher pressure. A duplex gage serves many useful purposes in indicating the operating condition of certain parts or types of equipment.

HYDRAULIC BOURDON TUBE GAGES.—Hydraulic Bourdon tube gages are used to indicate high pressures, as on hydraulic rams (cylinders) used on ship's steering gear and anchor windlasses. Because the pressure on these gages is so high, they are equipped with a slotted connecting link between the segment gear and the link adjustment to the tube. This prevents the pointer from slamming back to 0 when the pressure is suddenly released. Without such a slotted link, the pointer or the gage mechanism could be damaged by a sudden release of pressure in the tube. Note the slotted link adjustment shown in the gear mechanism of the hydraulic gage illustrated in figure 10-5. Many systems which employ this type of gage are equipped with gage snubbers (discussed later in this chapter) to prevent pressure surges from damaging the gage.



FP.170

Figure 10-5.—Slotted link in hydraulic Bourdon tube gage.



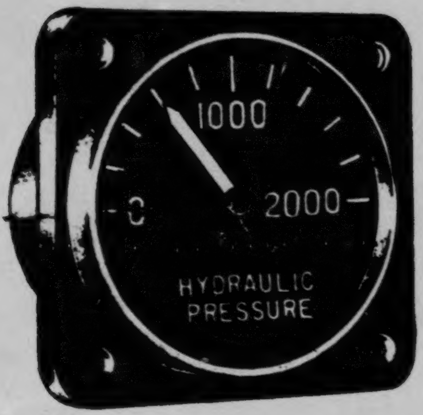
FP.171

Figure 10-6.—Hydraulic Bourdon tube gage.

Some of the hydraulic gages used by the Navy have dials which indicate both the psi pressure and the corresponding tons of load on the ram. (See fig. 10-6.) In the illustration, the main pointer of this gage rests on 0, but the maximum pointer registers between 3,800 and 3,900 on one scale and slightly over 150 on the other scale. This means that during the operation the highest pressure reached was slightly less than 3,900 tons of load on the ram. At one point during the operation, the highest psi registered by the main pointer was slightly over 150, and while it was registering this pressure it carried the maximum pointer with it. If the main pointer had registered 200, for example, the maximum pointer would be pointing to 5,100, the tons of load that had been exerted on the ram.

The spindle of the maximum pointer extends through a small hole in the gage face and has a small knob which screws into the spindle. By turning the knob, the operator can set the maximum pointer. Always check, therefore, to see if the main pointer carries the maximum pointer along with it.

Hydraulic Bourdon tube pressure gages on some naval aircraft are calibrated to register from 0 to 2,000 psi; on others they register from 0 to 4,000 psi. On gages designed for a range of 0 to 2,000 psi, the dial is calibrated with three major markings, the numerals 0, 1,000, and 2,000, and four intermediate graduations for reading to the nearest 200 psi. A gage of this type is shown in figure 10-7.



FP.172

Figure 10-7.—Hydraulic pressure gage (0 to 2,000 psi range).

On gages designed for a range of 0 to 4,000 psi, the dial is calibrated with five major markings with numerals 0, 1, 2, 3, and 4. One major intermediate graduation between each numeral and four minor intermediate markings between each major intermediate marking permit reading to the nearest 100 psi. On these gages the numeral reading must be multiplied by 1,000 to obtain the actual pressure in psi.

DIFFERENTIAL PRESSURE GAGE.—A differential pressure Bourdon tube gage is used to measure the difference in pressure between two pressure lines. (See fig. 10-8 (A).) Like the duplex gage, the differential gage contains two Bourdon tubes and two separate connections for different pressure sources. Unlike the duplex gage, the differential pressure gage has only one pointer and indicates the difference in pressure between the two pressure sources.

The Bourdon tubes in a gage of this type are connected in a definite manner so as to be able to record the difference in pressure from the two sources. The small Bourdon tube (fig. 10-8 (B)) is connected to a stationary base. Through a system of levers, it is connected to the large Bourdon tube. The base of the large tube works on a pivot, so that the base can move either to the right or to the left at any time. The movement of the two tubes counteract each other until the pressure in one tube is greater than the pressure in the other. Only this difference in pressure affects the linkage between the tubes and the pointer; therefore, the gage indicates the difference in pressure of the two sources.

The dial of the gage shown in figure 10-8 (A) has the 0 located at the bottom-left and allows the pointer to move only in one direction from 0. This design of differential pressure gage should be used in systems where the pressure from one source is always greater than that from the other. When the pressure from either source may be greater, a gage with a 0 at the top of the dial should be used. With the 0 in this position, the pointer has freedom of movement to the right or to the left of 0; thus indicating the source of the highest pressure.

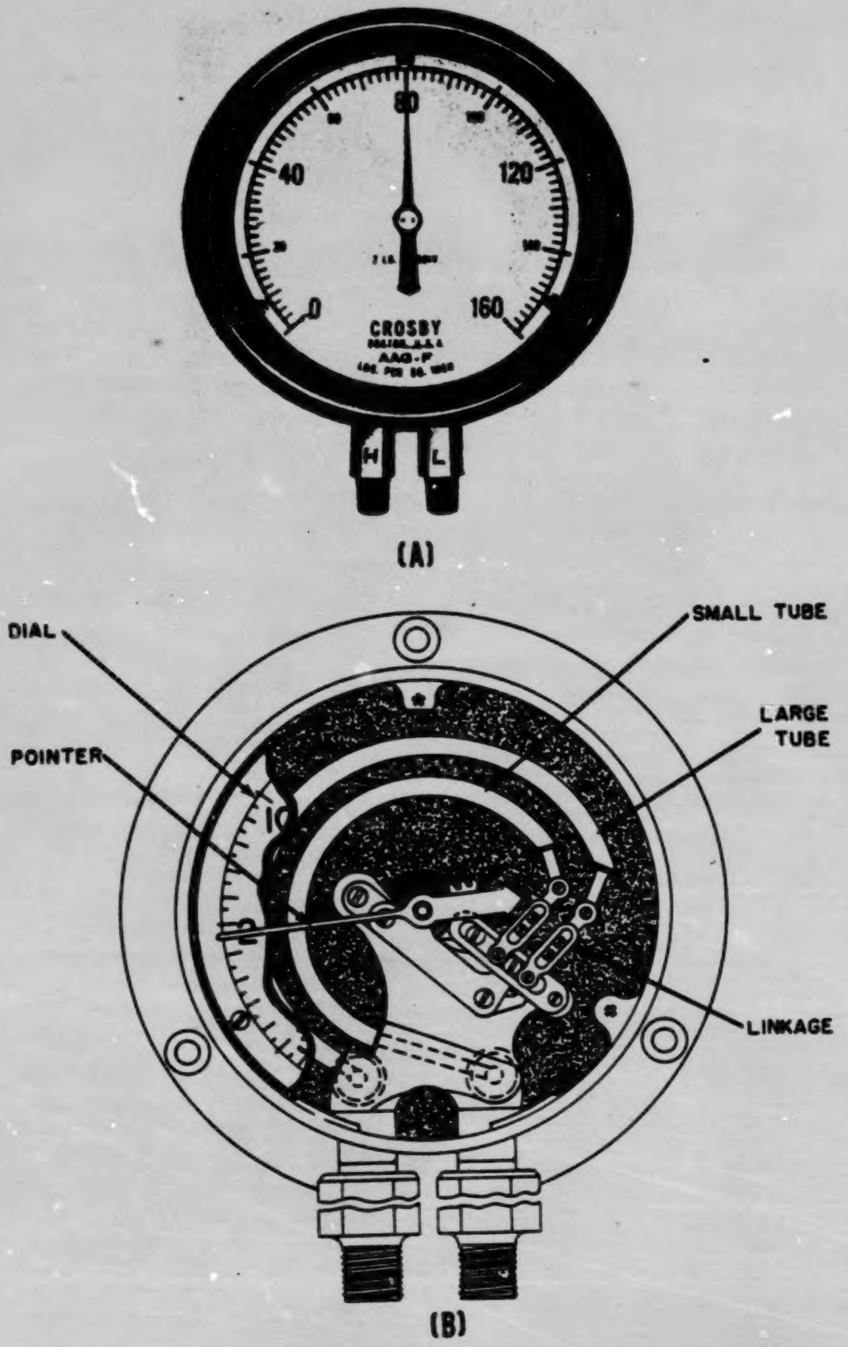
CAUTION: When a gage with 0 at the bottom left is used, turn on the valve to the high pressure source first, and then the valve to the low pressure source. Upon admittance to the line, pressure from the low pressure source will cause the pointer on the gage to revert toward 0.

Spiral and Helical Tubes

Two variations of the C-type Bourdon tube pressure gage are the spiral and the helical. The helical is sometimes referred to as helix. Both are made from tubing with a flattened cross section; both were designed to provide more travel of the tube tip, primarily for moving the recording pen of pressure recorders.

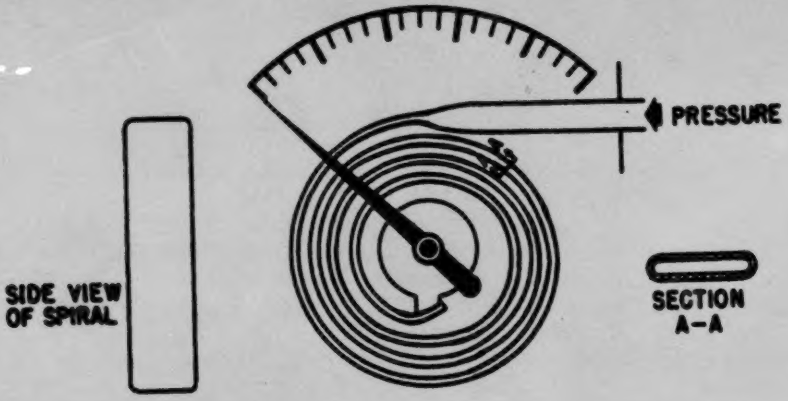
SPIRAL BOURDON TUBE.—The spiral form of the Bourdon tube (fig. 10-9) is made by winding the ordinary Bourdon tube in the form of a spiral, having several turns, instead of the approximately 250-degree arc of the conventional Bourdon tube. This arrangement does not change the operating principle of the Bourdon tube, but simply has the effect of producing a tip movement equal to the sum of the individual movements that would result from each part of the spiral considered as a simple Bourdon tube. A given pressure, therefore, causes greater tip movement than the C-shaped Bourdon type.

HELICAL BOURDON TUBE.—In the helical gage, the Bourdon tube element is wound in the form of a helix, as illustrated in figure 10-10. This arrangement increases the tip travel considerably. A center shaft is usually installed within the helix, and the linkage is arranged in such a manner that the shaft is


80
40
120
0
160
CROSBY
AAG-F
H
L
(A)
DIAL
SMALL TUBE
LARGE TUBE
POINTER
LINKAGE
(B)

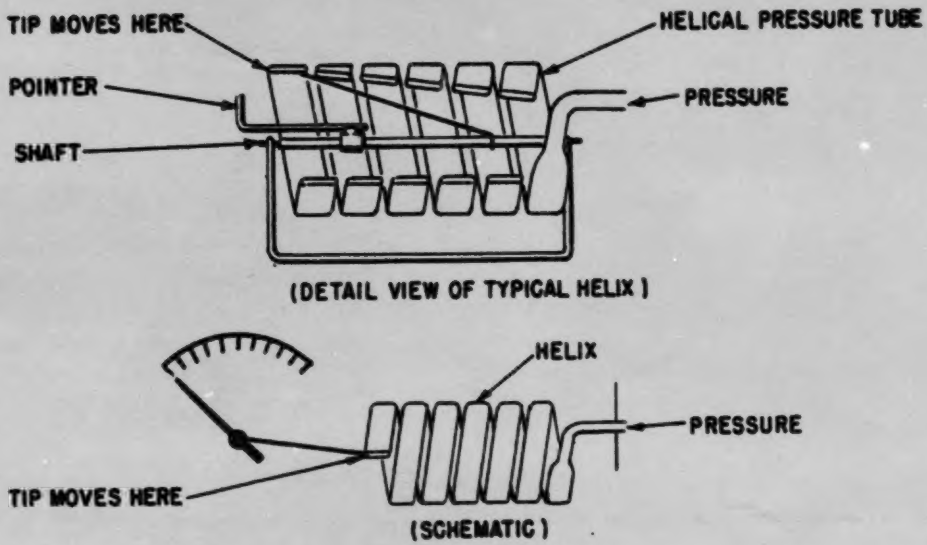
FP.173

Figure 10-8.—Differential pressure Bourdon tube gage.


PRESSURE
SIDE VIEW OF SPIRAL
SECTION A-A

FP.174

Figure 10-9.—Spiral Bourdon tube.


TIP MOVES HERE
HELICAL PRESSURE TUBE
POINTER
PRESSURE
SHAFT
(DETAIL VIEW OF TYPICAL HELIX)
HELIX
PRESSURE
TIP MOVES HERE
(SCHEMATIC)

FP.175

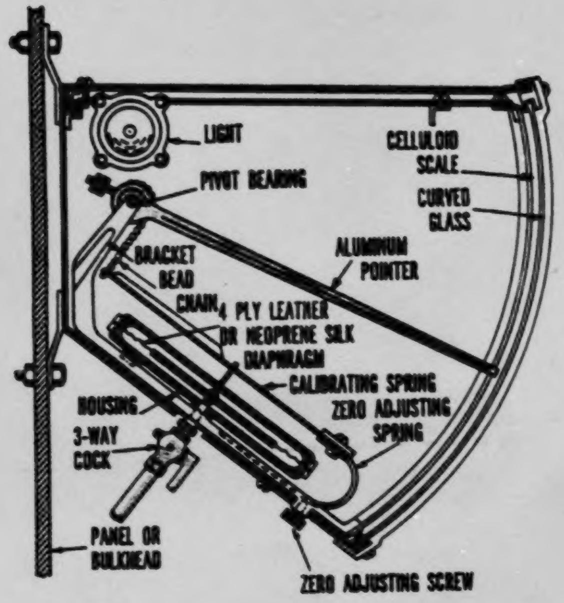
Figure 10-10.—Helical Bourdon tube gage.

rotated by the tip of the helix. The pointer, in turn, is driven through additional linkage by the shaft. This design transmits only the circular part of the tip movement to the pointer; this is the movement that is directly related to the change in pressure.

DIAPHRAGM GAGES

A diaphragm gage gives sensitive and reliable indications of small differences in pressure. It is often used to measure air pressure. This type of gage is usually designed by the manufacturer in accordance with specifications for a specific purpose and is calibrated accordingly. This does not mean, of course, that further adjustments may not be required when the gage is installed on equipment.

The indicating mechanism of a diaphragm gage consists of a tough, pliable, leather or neoprene rubber membrance connected to a metal spring which is attached by a simple linkage system to the gage pointer. Study the diaphragm gage illustrated in figure 10-11. Note the installation of the diaphragm in the gage frame and the position of all the parts of the gage. The size of the diaphragm affects the sensitivity in registering pressure—the larger the diaphragm the greater the sensitivity.



FP.176

Figure 10-11.—Diaphragm pressure gage.

One side of the diaphragm is exposed to the pressure being measured; the other side is exposed to the atmosphere. When no pressure is exerted against the diaphragm, both the diaphragm and the attached metal spring are in a neutral position. When pressure is applied, the diaphragm moves upward forcing the metal spring ahead of it. The spring is connected to the pointer with a length of kinkless bead chain. As the spring moves upward, it moves the pointer to a higher reading on the dial. When the pressure against the diaphragm decreases, the diaphragm returns toward its neutral position and pulls the metal spring and pointer with it. Thus, the reading on the scale of the diaphragm gage is directly proportional to the amount of pressure exerted on it by the force being measured.

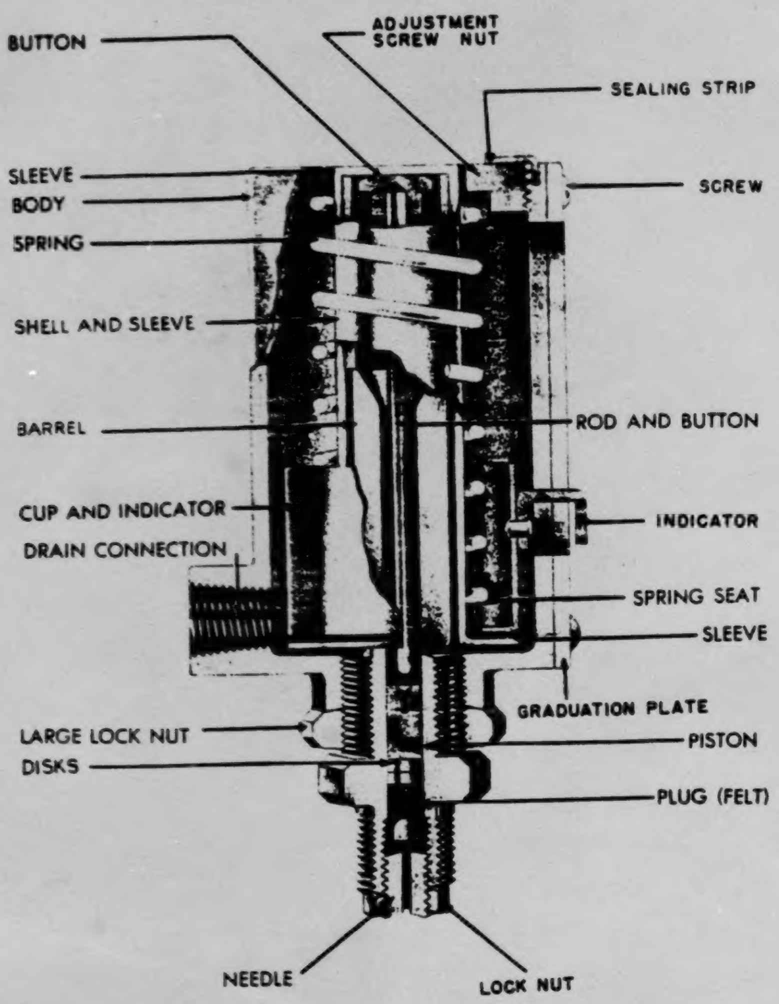
SPRING-LOADED PRESSURE GAGE

In some fluid power systems, the pressure fluctuates rapidly. These fluctuations can damage pressure gages, especially a delicate instrument as the Bourdon tube gage. Gage snubbers (discussed in the next section) are used in some systems to dampen these fluctuations; however, the spring-loaded direct-acting gage is sometimes used to measure pressure in such systems.

In the spring-loaded gage a piston is directly actuated by the fluid pressure to be measured. The piston moves through a cylinder against the resistance of a spring and carries a bar or indicator with it over a calibrated scale. In this manner all levers, gears, cams, and bearings are eliminated, and a sturdy instrument can be constructed.

Figure 10-12 shows the construction of the gage and the manner in which it operates. The parts up through the middle of the gage, from the needle at the bottom on through the packing piston and rod to the button at the top, form a unit that transmits fluid pressure to the sleeve against which the button rests. The sleeve surrounds the inner barrel of the gage. The sleeve is flanged at its base to provide a seat for a spring coiled around the barrel and for a cup to which the indicator is attached. Fluid pressure compresses the spring, and the barrel rises out of the body, carrying the indicator up with it. The indicator moves against a pressure scale on the face of the gage. (See fig. 10-13.)

The spring-loaded gage is calibrated by comparing gage readings with known pressures. A small error can be corrected by loosening four screws on the face of the gage and sliding the scale up or down under the pointer. For larger errors, the adjustment screw which holds the spring in place can be tightened if the gage is reading too high, or loosened if the reading is too low. Turning the adjustment screw varies the compression of the spring. A sealing strip is provided to lock the adjustment screw in place after calibration.


BUTTON
ADJUSTMENT SCREW NUT
SEALING STRIP
SLEEVE
BODY
SCREW
SPRING
SHELL AND SLEEVE
BARREL
ROD AND BUTTON
CUP AND INDICATOR
INDICATOR
DRAIN CONNECTION
SPRING SEAT
SLEEVE
GRADUATION PLATE
LARGE LOCK NUT
PISTON
DISKS
PLUG (FELT)
NEEDLE
LOCK NUT

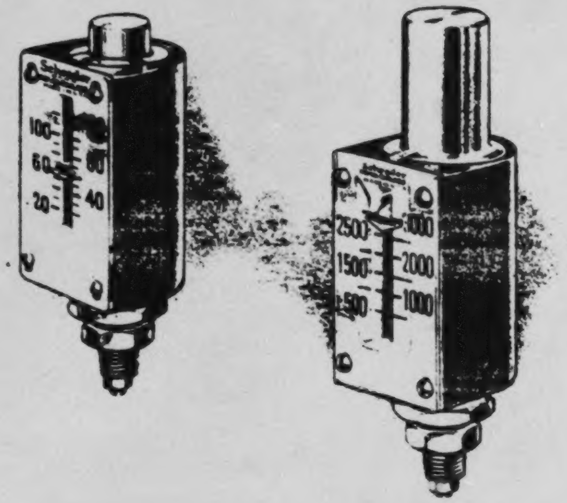
FP.177

Figure 10-12.—Spring-loaded gage—cutaway view.

While the spring-loaded pressure gage is satisfactory for ordinary fluid pressure measurements, it is not as accurate as the Bourdon tube gage. It is not a laboratory gage for exact readings, but a sturdily constructed working unit for practical use. It is available in various pressure ranges and is especially recommended for fluctuating loads. One advantage of this type gage is that it can be rebuilt very easily and economically.

The gage should be protected against vibration, excessive temperatures, corrosive or otherwise contaminated fluids, and sudden high pressure. A plug valve should be installed between the gage and the system so that pressure can be applied slowly to the gage, and so that it will be protected against strain when not in actual use.

These gages should not be used in a system in which maximum pressure may exceed the maximum designated gage reading. Dropping a gage may permanently damage the calibrated units. When gages are not in use they should be stowed in a dry place.



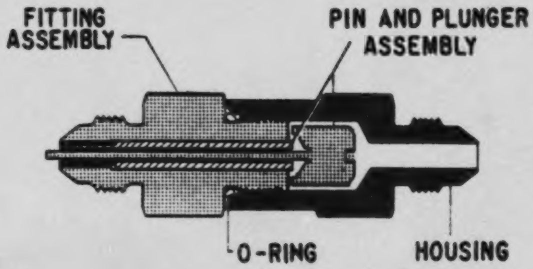
FP.178

Figure 10-13.—Spring-loaded gage scale.

GAGE SNUBBERS

The irregularity of impluses applied to the fluid power system by some power pumps/compressors causes the gage pointer to oscillate violently. This makes reading of the gage not only difficult but often impossible. Pressure oscillations and other sudden pressure changes existing in fluid power systems will also effect the delicate internal mechanism of gages and cause either complete destruction of the gage or, often worse, partial damage, resulting in false readings. A pressure gage snubber is therefore installed in the line to the pressure gage.

The purpose of the snubber is to dampen the oscillations and thus provide a steady reading and a protection for the gage. The basic components of a snubber are the housing, fitting assembly with a fixed orifice diameter, and a pin and plunger assembly, as illustrated in figure 10-14. The snubbing action is obtained by metering fluid through the snubber. The fitting assembly orifice restricts the amount of fluid that flows to the gage, thereby snubbing the force of a pressure surge. The pin is pushed and pulled through the orifice of the fitting assembly by the plunger, keeping it clean and at a uniform size.



FP.179

Figure 10-14.—Pressure gage snubber.

PRESSURE CONTROL DEVICES

Safe and efficient operation of fluid power systems, system components, and related equipment requires a means of controlling pressure. There are several different types of pressure control devices used in fluid power systems. Some of these devices are used to maintain the desired pressure in the system, some are designed to prevent excessive pressure buildup and damage to the system, and some are used to reduce pressure to one or more subsystems. For example, a system with a number of subsystems may require 3,000 psi to operate all subsystems except one, which requires only 1,500 psi. A pressure control valve is used to maintain the 3,000 psi in the main system, and a pressure reducing valve is used to reduce the pressure to 1,500 psi before it enters the one subsystem. These and several other types of pressure control devices are described in the following sections.

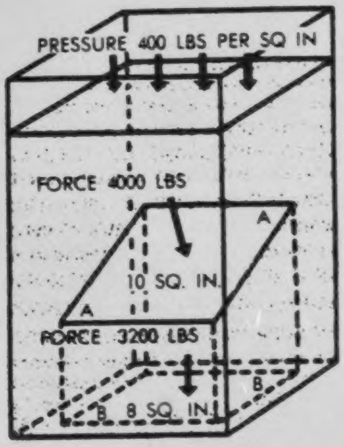
Most pressure control valves are of the type which contain two systems of moving parts whose joint action is responsible for the operation of the valve. As stated in chapter 9, this type is classified as compound rather than simple. Some of the reasons compound valves are used for the control of pressure are explained in the next section under relief valves.

The manner in which the most complicated pressure control valve operates will always conform to the hydraulic principles discussed in chapter 2. The valve will open or close because pressures are different over equal areas, because pressures are acting over unequal areas, or a combination of both reasons. In each instance, inequality of opposed forces causes the valve to open or close. The forces may be set up by the opposition of fluid pressures, or by fluid pressure acting against a mechanical resistance; for example, the resistance set up by a spring.

Like all forces, the force exerted in a certain direction on the face of a valve is always exerted on an area standing exactly at a right angle to that direction. Thus in figure 10-15, if the fluid is under a pressure of 400 psi and the slanting surface (A) has an area of 10 square inches, the force acting in a slanting direction, at right angles to that surface, is 4,000 pounds. The force acting directly downward on surface (A), however, depends upon the horizontal area (B), directly beneath (A). If (B) has an area of 8 square inches, the downward force acting on surface (A) is 3,200 pounds (400 x 8).

RELIEF VALVES

A relief valve is simply a pressure limiting device. It is commonly used to prevent the pressure of a confined fluid from building up to a point at which the container would burst. Since it is used to protect the system from excessive pressures, the relief valve is sometimes referred to as a safety valve. The "pop-off" valve on a steam boiler and the safety valve on a hot water tank are relief valves. The pressure cap on an automobile radiator is a relief valve, used to prevent pressure from building up too high and bursting the radiator.



FP.180

Figure 10-15.—Pressure acting on a slanted surface.

Some fluid power systems, even when operating normally, may temporarily develop dangerous excess pressure; for example, when an unusually strong work resistance is encountered. Relief valves are used to control this excess pressure. Their purpose is not to maintain flow or pressure at a given amount, but to prevent pressure from rising above a definite level when the system is temporarily overloaded.

The main system relief valve must be large enough to allow the full output of the hydraulic pump to be delivered back to the reservoir. In the case of a pneumatic system, the relief valve controls excess pressure by discharging the excess fluid into the atmosphere.

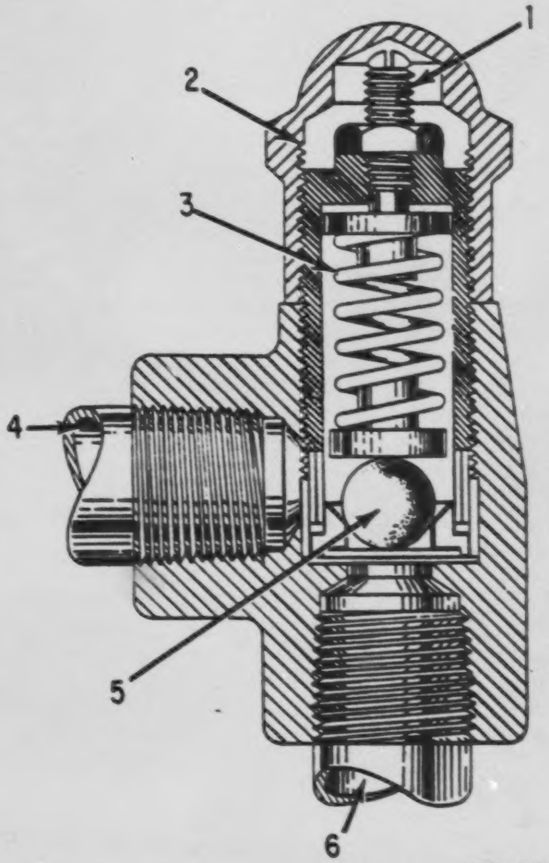
Smaller relief valves, similar in design and operation to the main system relief valve, are often used in isolated parts of the system where a check valve or a directional control valve prevents pressure from being relieved through the main system relief valve and where pressures must be relieved at a point lower than that provided by the main system relief valve. These small relief valves are also used to relieve pressures caused by thermal expansion (see glossary) of the fluids. Since the amount of fluid to be relieved is small, the valve can be small and still do its job.

All relief valves have an adjustment for increasing or decreasing the pressure at which they will relieve. Some relief valves are equipped with an adjusting screw for this purpose. The adjusting screw is unusally covered with a cap, which must be removed before adjustment can be made. Some type of locking device, such as a lock nut, is usually provided to prevent the adjustment from changing through vibration. Other types of relief valves are equipped with a handwheel for making adjustments to the valve. Either the adjusting screw or handwheel is turned clockwise to increase the pressure at which the valve will relieve.

A simple two-port relief valve is shown in figure 10-16. Fluid under system pressure enters port (6) and pushes upward against the ball (5). If the pressure increases to a point high enough to overcome the force of spring (3), the ball will be pushed off its seat, and the fluid from the system can flow out port (4) to return, or to the atmosphere in pneumatic systems. When the system pressure decreases to normal, the spring (3) forces the ball (5) on its seat. The adjusting screw (1) increases or decreases the force of the spring, requiring more or less pressure to unseat the ball.

Various modifications of the simple relief valve are used and efficiently serve the requirements of some fluid power systems. However, many systems require compound relief valves. For a better understanding of the operation of relief valves, some of the undersirable characteristics of the simple relief valve are discussed in the following paragraphs.

It is because simple relief valves are unsatisfactory for some applications that compound relief valves were developed. A simple relief valve, such as the one illustrated in figure 10-16, with a suitable spring adjustment can be set so that it will open when the system pressure increases to 500 psi, for example. When it does open, however, the volume of flow to be handled may be greater than the capacity of the valve, so that pressure in the system may increase as much as several hundred psi above the set pressure before the valve spring brings the pressure under control. A simple relief valve would be effective under these conditions only if it were very large. In that case, however, it would operate stiffly and the valve element would chatter back and forth.

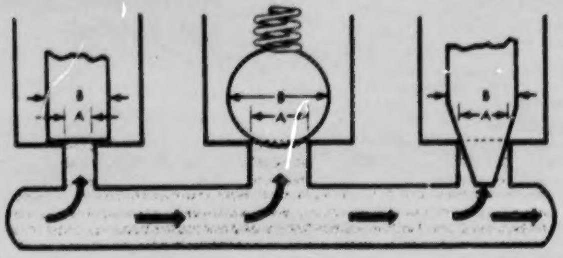


FP.181

1. Pressure adjusting screw.
2. Adjusting screwcap.
3. Compression spring.
4. Return port.
5. Ball.
6. Pressure port.

Figure 10-16.—Simple two-port relief valve.

In addition, the valve will not close until the pressure decreases to a point somewhat below the opening pressure. As indicated in figure 10-17, the surface area of the valve element must be larger than the pressure opening if the valve is to seat satisfactorily. The pressure in the system acts on the area of the valve element open to it. In each case in figure 10-17, the force exerted directly upward by system pressure when the valve is closed depends on the horizontal area across the valve at (A). The moment the valve opens, however, the upward force exerted depends on the horizontal area of the valve element at (B), which



FP.182

Figure 10-17.—Pressure acting on different areas.

is necessarily greater than the area at (A). This causes an upward jump in the action of the valve immediately after it opens, and it also sets up a greater force opposed to the closing of the valve than was required to open it. As a result, the valve will not close until the pressure has decreased to a point somewhat lower than the pressure required to open it. The same pressure acting over different areas produces forces proportional to the areas.

For example, assume that a valve of this type is set to open at 500 psi. (Refer to fig. 10-17.) When the valve is closed, the pressure acts on the area (A). If this area is 0.5 square inch, an upward force of 250 pounds (500 x 0.5) will be exerted on the valve at the moment of opening. With the valve open, however, the pressure acts on the area at (B). If the area at (B) is 1 square inch, the upward force is 500 pounds, or double the force at which the valve actually opened. For the valve to close, pressure in the system would have to decrease well below the point at which the valve opened. The exact pressure at which the valve would close depends upon certain relations of the particular shapes of the valve element.

In some hydraulic systems, there is a pressure in the return line. This "back pressure" is caused by restrictions in the return line and, of course, will vary in relation to the amount of fluid flowing to return. This pressure acts on the top of the valve element and will increase the force necessary to open the valve and relieve system pressure.

It follows that simple relief valves have a tendency to open and close rapidly as they "hunt" above and below the set pressure, causing pressure pulsations and undesirable vibrations and producing a noisy chatter. Compound relief valves use the principle of operation of simple relief valves for one stage of their action—that of the pilot valve—but provision is made to limit the amount of fluid that the pilot valve must handle, and thereby avoid the weaknesses of simple relief valves. (A pilot valve is a small valve used for operating another valve.)

The operation of a compound relief valve is illustrated in figure 10-18. In view (A), the main valve, which consists of a piston, stem, and spring, is closed, blocking flow from the high-pressure line to the reservoir. Fluid in the high-pressure line flows around the stem of the main valves as it flows to the actuating unit. The stem of the main valve is hollow (the stem passage), and contains the main spring which forces the main valve against its seat. When the pilot valve is open the stem passage allows fluid to flow from the pilot valve, around the main spring, and down to the low-pressure or return line.

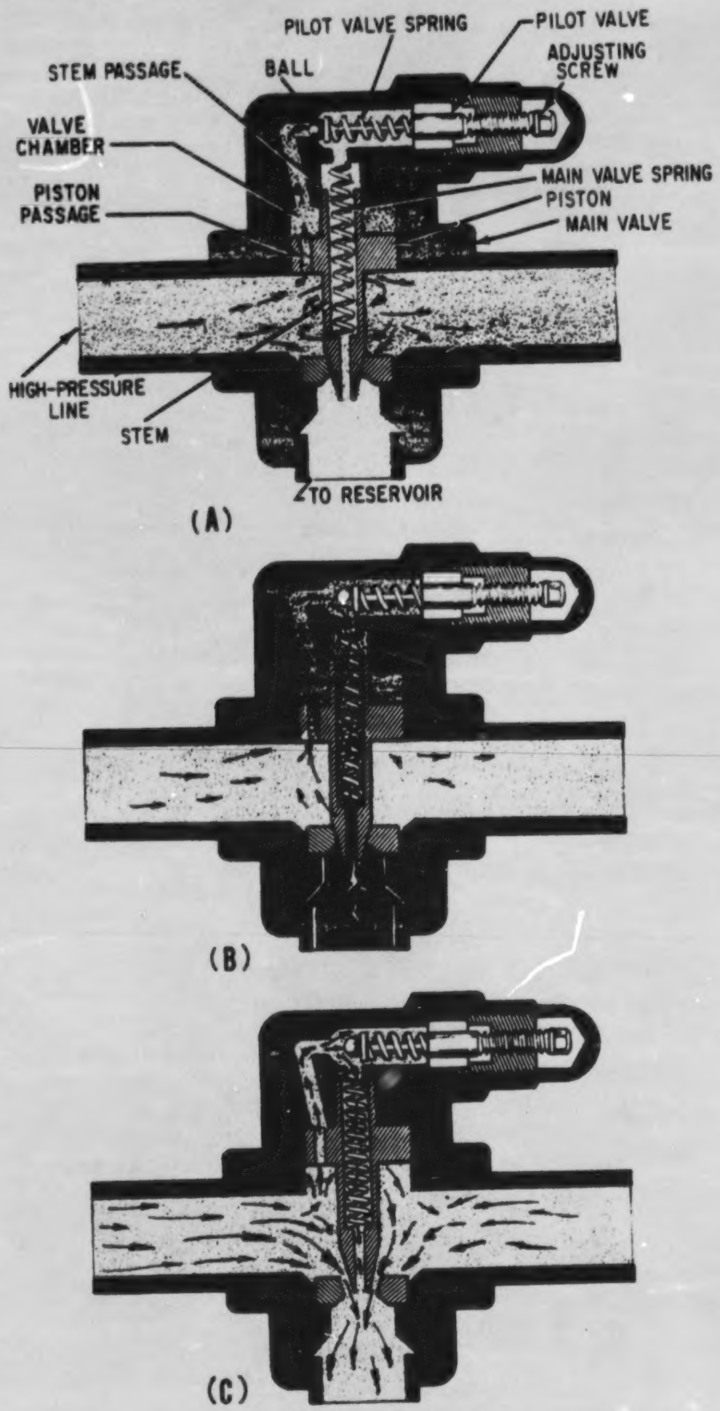
There is also a narrow passage through the main valve piston. This passage connects the high-pressure line to the valve chamber.

The pilot valve is a small, ball type, spring-loaded check valve, which connects the top of the passage from the valve chamber with the passage through the main valve stem. The pilot valve spring tension can be adjusted by turning the adjusting screw. The pressure at which the valve will relieve depends on the tension of the spring.

Fluid at line pressure flows through the narrow piston passage to fill the chamber. Because the line and the chamber are connected, the pressure in both are equal. The top and bottom of the main piston have equal areas; therefore, the hydraulic forces acting upward and downward are equal, and there is no tendency for the piston to move in either direction. The only other force acting on the main valve is that of the main spring, which holds it closed.

The pilot valve is the control unit. Its spring is so adjusted that the ball will unseat when pressure reaches the preset limit. At normal operating pressure the ball remains seated.

When the pressure in the high-pressure line increases to the point at which the pilot valve is set, the ball unseats, and opens the valve chamber through the valve stem passage to the low-pressure return line. (See fig. 10-18 (B).) Fluid immediately begins to flow out of the chamber, much faster than it can


PILOT VALVE SPRING
PILOT VALVE
ADJUSTING SCREW
STEM PASSAGE
BALL
VALVE CHAMBER
PISTON PASSAGE
MAIN VALVE SPRING
PISTON
MAIN VALVE
HIGH-PRESSURE LINE
STEM
TO RESERVOIR
(A)
(B)
(C)

FP.183

Figure 10-18.—Operation of compound relief valve.

flow through the narrow piston passage. As a result the chamber pressure immediately drops, and the pilot valve begins to close again, restricting the outward flow of fluid. Chamber pressure therefore increases, the valve opens, and the cycle repeats.

So far, the only part of the valve that has moved appreciably is the pilot, which functions just like any other simple spring-loaded relief valve. Because of the small size of the piston passage, there is a severe limit on the amount of relief it can give the system. All the pilot valve can do is limit fluid pressure in the valve chamber above the main piston to a preset maximum pressure, by allowing excess fluid to flow through the piston passage, through the valve chamber, and through the stem passage into the return line. When pressure in the system increases to a value which is above the flow capacity of the pilot valve, the main valve opens, permitting excess fluid to flow directly to return. This is accomplished in the following manner.

As system pressure increases, the upward force on the main piston overcomes the downward force, which consists of the tension of the main piston spring and the pressure of the fluid in the valve chamber. (See fig. 10-18 (C).) The piston then rises, unseating the stem, and allows the fluid to flow from the system pressure line directly into the return line. This causes system pressure to decrease rapidly, since the main valve is designed to handle the complete output of the pump. When the pressure returns to normal, the pilot spring forces the ball on the seat. Pressures are then equal above and below the main piston, and the main spring forces the valve to seat.

As can be seen, the compound valve overcomes the greatest limitation of a simple relief valve by limiting flow through the pilot valve to such quantities as it can satisfactorily handle. This limits the pressure above the main valve, and enables the main line pressure to open the main valve. In this way, the system is relieved when an overload exists.

COUNTERBALANCE VALVES

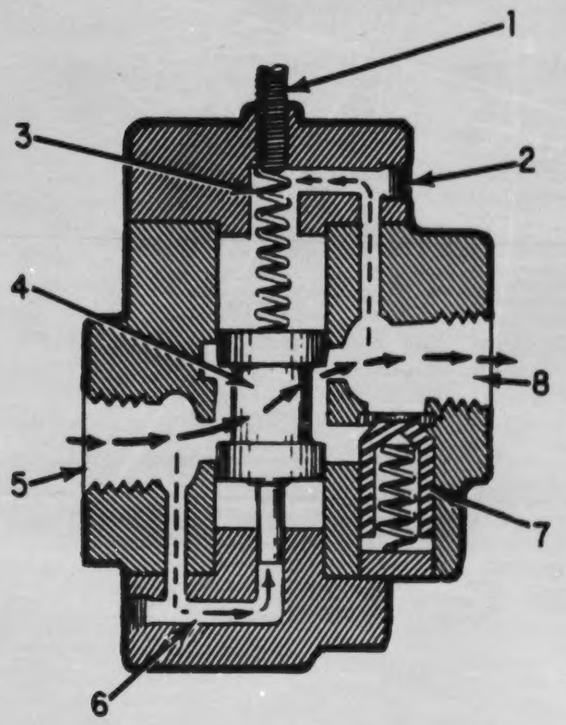
The purpose of a counterbalance valve is to permit free flow of fluid in one direction and to maintain a resistance to flow in the other direction until a certain pressure is reached. The valve is normally located in the line between the directional control valve and the outlet of a vertically mounted actuating cylinder which supports weight or must be held in position for a period of time. The counterbalance valve serves as a hydraulic resistance to the actuating cylinder. For example, counterbalance valves are used in some hydraulically operated fork lifts. The valve offers a resistance to the flow from the actuating cylinder when the fork is lowered. It also helps to support the fork in the UP position.

Counterbalance valves are also used in some late model air launched weapons loaders. In this case, the valve is located in the top of the lift cylinder. The valve requires 250 psi to lower the load. If adequate pressure is not available, the load cannot be lowered, thus preventing collapse of the load due to any malfunction of the hydraulic system.

One type of counterbalance valve is illustrated in figure 10-19. The valve element is a balanced spool valve (4). The spool valve consists of two pistons permanently fixed on either end of a shaft. The inner surface areas of the pistons are equal; therefore, pressure acts equally on both areas regardless of the position of the valve, and has no effect on the movement of the valve—hence, the term balanced. The shaft area between the two pistons provides the area for the fluid to flow when the valve is open. A small pilot valve is attached to the bottom of the spool valve.

When the valve is in the closed position, the top piston of the spool valve blocks the discharge port (8). With the valve in this position, fluid, flowing from the actuating unit, enters the inlet port (5). The fluid cannot flow through the valve because the discharge port (8) is blocked. However, fluid will flow through the pilot passage (6) to the small pilot piston. As the pressure increases, it acts on the pilot piston until it overcomes the preset pressure of spring (3). This forces the spool up and allows the fluid to flow around the shaft of the spool valve and out the discharge port (8). Figure 10-19 shows the valve in this position.

During reverse flow, the fluid enters port (8). The spring (3) forces the spool valve (4) to the closed position. The fluid pressure overcomes the spring tension of check valve (7). The check valve opens and allows free flow around the shaft of the spool valve and out port (5).



1. Adjustment screw.
2. Internal drain.
3. Spring.
4. Spool.
5. Pressure inlet or reverse free flow outlet.
6. Pilot passage.
7. Check valve.
8. Discharge outlet or reverse free flow inlet.

FP.184

Figure 10-19.—Counterbalance valve.

The operating pressure of the valve can be adjusted by turning the adjustment screw (1), which increases or decreases the tension of the spring. This adjustment depends on the weight that the valve must support.

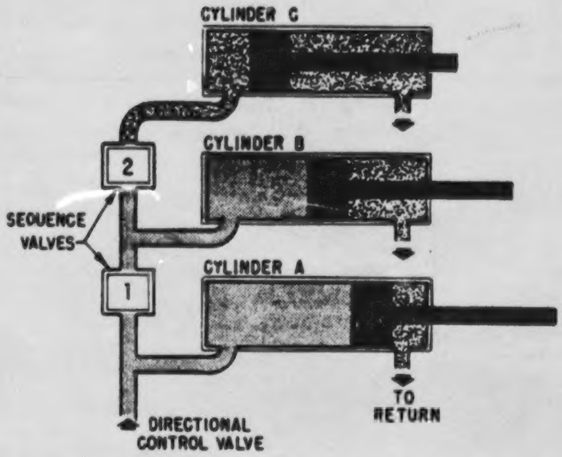
It is normal for small amounts of fluid to leak around the top piston of the spool valve and into the area around the spring (3). An accumulation would cause additional pressure on the top of the spool valve. This would require additional pressure to open the valve. The drain (2) provides a passage for this fluid to flow to port (8).

SEQUENCE VALVES

As described in chapter 9, the orifice check valve is sometimes used to control the sequence of operation in one direction of two or more actuating devices. Some fluid power systems require a more positive means of controlling the sequence of operation. A sequence valve is used in these cases. As the name implies, a sequence valve is used to control a sequence of operations; that is, enable one unit to automatically set another unit into motion. An example of the use of a sequence valve is in an aircraft landing gear actuating system.

In a landing gear actuating system the landing gear doors must open before the landing gear starts to extend. Conversely, the landing gear must be completely retracted before the doors close. A sequence valve installed in each landing gear actuating line performs this function.

Figure 10-20 shows an installation of two sequence valves which control the sequence of operation of three actuating cylinders. Fluid from the directional control valve is free to flow into cylinder (A). The first sequence valve (1) blocks the passage of fluid until the piston in cylinder (A) moves to the end of its stroke. At this time, sequence valve (1) opens, allowing fluid to enter cylinder (B). This action continues until all three pistons complete their strokes.



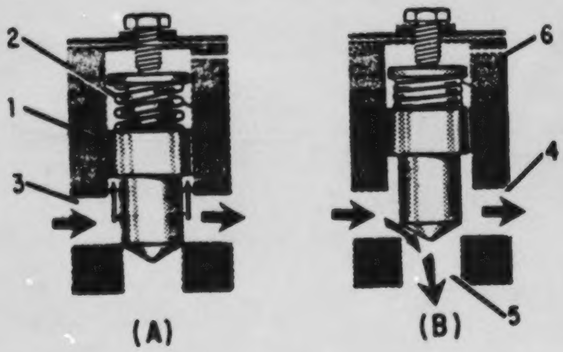
FP.185

Figure 10-20.—Installation of sequence valves.

There are various types of sequence valves. Some are pressure controlled and some are mechanically controlled. One type of sequence valve operates similar to the counterbalance valve just described. In fact, valves are available which can be utilized as either a counterbalance valve or sequence valve. Two types of sequence valves are described in the following paragraphs. The first is pressure controlled and the second is mechanically controlled.

Pressure Controlled Sequence Valve

The operation of a typical pressure controlled sequence valve is illustrated in figure 10-21. The opening pressure is obtained by adjusting the tension of spring (2), which normally holds the piston (1) in the closed position. Note that the top part of the piston has a larger diameter than the lower part. Fluid from the directional control valve enters port (3), flows around the lower part of the piston (1) and enters the outlet port (4), where it flows to the first (primary) unit to be operated. This fluid pressure acts against the lower surface of the larger part of the piston. When the pressure of the fluid is below the adjusted setting, the force acting upward against this surface area of the piston is less than the downward force of the spring (2). This holds the piston down and the valve is in the closed position as shown in figure 10-21 (A).



1. Piston.
2. Spring.
3. Entrance port.
4. Outlet port to primary unit.
5. Outlet port to secondary unit.
6. Drain.

FP.186

Figure 10-21.—Operation of pressure controlled sequence valve.

When the primary actuating unit completes its operation, pressure in the line to the actuating unit increases and, therefore, the pressure in the valve increases. When the pressure increases sufficiently to overcome the force of spring (2), piston (1) rises. The valve is then in the open position, as shown in figure 10-21 (B). The fluid entering the valve takes the path of least resistance and flows through port (5) to the secondary unit.

A drain passage (6) is provided to allow any fluid, which leaks past the piston, to flow from the top of the valve. In the case of hydraulic systems, this drain line is usually connected to the main return line. These valves usually contain a check valve to allow free reverse flow from the actuating units. However, the sequencing action is provided in only one direction of flow.

Mechanically Operated Sequence Valves

Figure 10-22 illustrates a mechanically operated sequence valve. This valve is operated by the in and out movement of the plunger which extends through the body of the valve.

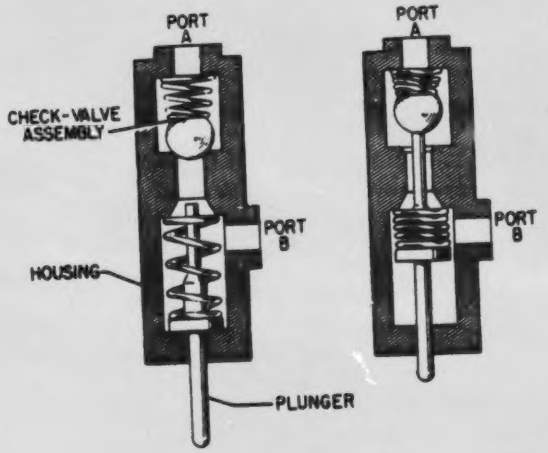


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Figure 10-22.—Mechanically operated sequence valve.

The plunger is held in the extended position by a spring. The valve is mounted so that the plunger will be depressed by the primary unit.

A check valve is incorporated between the fluid ports in the body. The check valve, either a ball or a poppet, is held against the seat by a spring. The check valve is unseated either by the plunger as it is depressed into the valve or by fluid under pressure entering port (B).

Port (A) and the actuator of the primary unit are connected with a common line from the directional control valve. Port (B) is connected with a line to the actuator of the secondary unit. When fluid under pressure flows from the directional control valve to the primary unit, it also flows through port (A) to the seated check valve in the sequence valve. In order to operate the secondary unit, the fluid must flow through the sequence valve. The valve is located in such a position that the primary unit, as it completes its operation, will depress the plunger. The plunger unseats the check valve and allows the fluid to flow through the valve, out port (B), and to the secondary unit.

This type sequence valve permits flow in the opposite direction. Fluid enters port (B) and flows to the check valve. Although this is return flow from the actuating unit, the fluid is under sufficient pressure to overcome spring tension and unseat the check valve and flow out through port (A).

PRESSURE REGULATORS

As the term implies, pressure regulators are used in fluid power systems to regulate the pressure. In pneumatic systems, the valve commonly referred to as a pressure regulator serves to reduce pressure. This type valve is discussed later in this chapter under pressure reducing valves. The pressure switch, also described later, is often used in pneumatic systems to regulate pressure. The pressure regulator described in the following paragraphs is utilized in hydraulic systems.

Pressure regulators, often referred to as unloading valves, are used in hydraulic systems to unload the pump and to maintain and regulate system pressure between the maximum and minimum. All hydraulic systems do not require pressure regulators. The open-center system does not require a pressure regulator. Many systems are equipped with variable displacement pumps, which contain a pressure regulating device as described in chapter 8. Although manufacturers are leaning more toward the use of variable displacement pumps, there are many closed-center hydraulic systems that utilize constant displacement pumps and, therefore, require a pressure regulator. (Open- and closed-center hydraulic systems are described in chapter 4.)

Pressure regulators are made in a variety of types by various manufacturers; however, the basic operating principles of all regulators are similar to the one illustrated in figure 10-23. View (A) shows the regulator in the cut-in position and view (B) in the cutout position.

A regulator is said to be in the cut-in position when it is directing fluid under pressure into the system. In the cutout position, the fluid in the system after the regulator is trapped at the desired pressure, and the fluid from the pump is bypassed into the return line and back to the reservoir. To prevent constant cutting in and cutting out (chatter), the regulator is designed to cut in at a pressure somewhat lower than the cutout pressure. This difference is known as differential or operating range. For example, assume that a pressure regulator is set to cut in when the system pressure drops below 600 psi, and cut out when the pressure rises above 800 psi. The differential or operating range is 200 psi.

Referring to figure 10-23, assume that the piston (5) has an area of 1 square inch, the steel ball of the bypass valve (1) has a cross-sectional area of one-fourth square inch, and the piston spring (6) provides 600 pounds of force pushing the piston down. When the pressure in the system is less than 600 psi, fluid from the pump enters the input port (2), flows to the top of the regulator, and to the check valve (3). When the pressure of this input fluid increases to a value above the pressure of the fluid in the system side of the check valve and the force of the check valve spring, the check valve opens and fluid flows into the system and to the bottom of the regulator against the piston (5). Until the pressure is great enough to force the piston upward and unseat the ball, the fluid is directed through the system connection port (4) to the system. The regulator is then in the cut-in position, as shown in view (A) of figure 10-23.

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CHAPTER 4

FUELS AND LUBRICANTS

Fuels and lubricants for gasoline and diesel engines are byproducts of petroleum. Petroleum, often called crude oil, means "rock oil." Petroleum products include gasoline, kerosene, diesel fuel, lubricating oils, gear lubricants and greases. Many different products are added to the raw byproducts to obtain a fuel or lubricant that will perform efficiently in modern equipment.

Fuels and lubricants may be contaminated by dirt, rust, water, or by accidental combination with other types of petroleum products. Avoiding such contamination is vital if the products are to serve the purposes for which they are intended. DIRT and WATER in fuels and lubricants are primary causes of premature engine failure. CLEANLINESS in handling fuels and lubricants cannot be overemphasized.

REFINING CRUDE OIL

Crude oil would ruin an engine if the impurities were not removed. The impurities are removed by the refining process which also separates the oil into various petroleum products. (See fig. 4-1.)

You have seen a teakettle boil. Heating the water in the kettle changes it to gas or vapor in the form of steam at a certain temperature. Many kinds of liquids change to gases, or are said to VAPORIZE, at different temperatures. Heating petroleum, which is a mixture of liquids, will change the liquids to gases one by one. Cooling changes each gas back to liquid form through condensation. This process of separating substances from one another is called DISTILLATION.

Distillation drives gasoline vapors from the crude oil first, because gasoline has a lower boiling point and vaporizes before other petroleum products. Substances with higher boiling points, like kerosene and the gas-oil from which we get most of our diesel fuel, are given off next. After the gas-oil has been collected, lubricating oils are distilled, the lightest first (lube distillates), and then the heavier ones (commonly called bottoms).

You will hear also about propane and butane fuels, which are byproducts of natural gas. (Notice in figure 4-1 that gas is taken from a cavity in the earth that is between the oil and the rock formation just above the oil.) These liquids must be collected and stored under pressure because they change into gas when released to the atmosphere. Liquid propane becomes a gas at a temperature of -43° F; liquid butane, at 33° F. Although seldom used as a fuel for automotive equipment, small amounts of these liquid gases have been used to start engines in very cold climates. Some manufacturers believe that internal combustion engines can operate more economically with butane fuel than with gasoline. Gasoline and diesel oil, however, continue to be the most efficient fuels for internal combustion engines.

PROPERTIES OF GASOLINE

Gasoline contains carbon and hydrogen in such proportions that the gasoline burns freely and liberates HEAT ENERGY. It evaporates at ordinary temperatures. Because gasoline vapors are heavier than air, they sink to the ground. To decrease the fire hazard of having the gasoline vapors in a confined place where spontaneous combustion could take place, the enclosure in which gasoline is used SHOULD BE THOROUGHLY VENTILATED THROUGH OPENINGS NEAR THE FLOOR.

If all the potential heat energy contained in a gallon of gasoline could be converted into work, a motor vehicle could run hundreds of miles on each gallon. However, only a small percentage of this heat energy is converted into mechanical energy by the engine.

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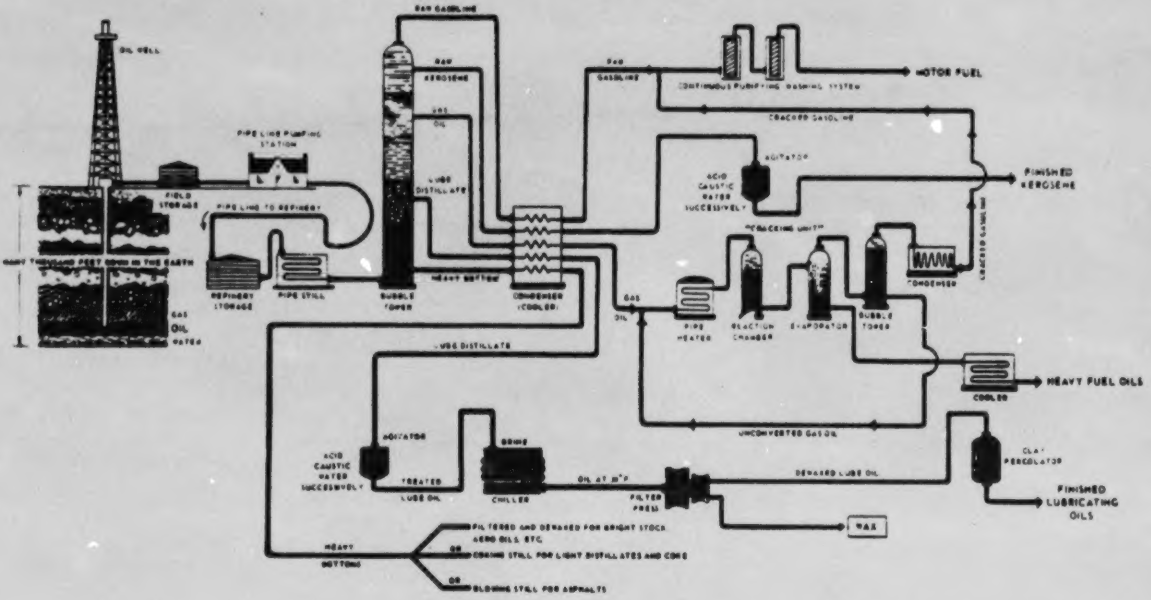

OIL WELL
PIPE LINE PUMPING STATION
FIELD STORAGE
PIPE LINE TO REFINERY
MANY THOUSAND FEET DOWN IN THE EARTH
GAS
OIL
WATER
REFINERY STORAGE
PIPE STILL
RAW GASOLINE
RAW KEROSENE
GAS OIL
LUBE DISTILLATE
HEAVY BOTTOM
BUBBLE TOWER
CONDENSER (COOLER)
RAW GASOLINE
CONTINUOUS PURIFYING WASHING SYSTEM
MOTOR FUEL
CRACKED GASOLINE
AGITATOR
ACID CAUSTIC WATER SUCCESSIVELY
FINISHED KEROSENE
"CRACKING UNIT"
CONDENSER
CRACKED GASOLINE
GAS OIL
PIPE HEATER
REACTION CHAMBER
EVAPORATOR
BUBBLE TOWER
COOLER
HEAVY FUEL OILS
UNCONVERTED GAS OIL
LUBE DISTILLATE
AGITATOR
ACID CAUSTIC WATER SUCCESSIVELY
TREATED LUBE OIL
BRINE
CHILLER
OIL AT 10°F
FILTER PRESS
DEWAXED LUBE OIL
CLAY PERCOLATOR
FINISHED LUBRICATING OILS
WAX
HEAVY BOTTOMS
FILTERED AND DEWAXED FOR BRIGHT STOCK AERO OILS, ETC.
OR COKING STILL FOR LIGHT DISTILLATES AND COKE
OR BLOWING STILL FOR ASPHALTS

81.71

Figure 4-1.—Typical chart tracing crude oil from well to finished product.

Most authorities consider the power losses within the engine to be as follows:

Engine	Percent of Power Loss
Cooling System	35
Exhaust Gases	35
Engine Friction	5 to 10
Total.	75 to 80

The question of what is ideal gasoline is more theoretical than practical. Every manufacturer recommends the octane rating of the gasoline he feels is best for the engines he produces. Besides engine design, factors like the weight of the vehicle, the terrain and highways over which it is to be driven, and the climate and altitude of the locality also determine what gasoline is best to use. All other factors being equal, these may be considered as some of the properties of the best gasoline: good antiknock quality, a minimum content of foreign matter, a volatility which makes starting easy and allows smooth acceleration and economical operation.

VOLATILITY

The blend of a gasoline determines its VOLATILITY—that is, its tendency to change from a liquid to a vapor at any given temperature. The rate of vaporization increases as the temperature of the gasoline rises.

No standard for gasoline volatility meets all engine operating requirements. The volatility must be high enough for easy starting and acceleration. Ordinarily the proper starting mixture is about 15 parts of air to 1 part of fuel, but in very cold weather more fuel must be admitted to the cylinders through the use of the choke in the carburetor for quicker starting. In polar regions, a gasoline of higher volatility makes starting easier; it also helps keep the crankcase from becoming diluted by gasoline seeping past the piston and the piston rings while the engine is being choked.

On the other hand, a gasoline of low volatility brings about better fuel economy and combats VAPOR LOCK (the formation of vapor in the fuel lines in a quantity sufficient to block the flow of gasoline through the system). In the summer and in hot climates, especially, fuels with low volatility lessen the tendency toward vapor lock.

PURITY

Engine efficiency depends to some extent on the PURITY of gasoline. Gums and sulfur are removed from crude oil in the refining process. Gums in gasoline cause sticking valves and form hard baked surfaces within the cylinders. Sulfur unites with water to form sulfuric acid, which corrodes engine parts. Modern refining proesses have reduced the sulfur and other foreign matter content of gasoline, thus minimizing the damage to engine parts as well as cutting down engine maintenance.

ANTIKNOCK QUALITY AND DETONATION

Reviewing the process of combustion in chapter 2 will help you understand the ANTIKNOCK quality of gasoline. When any substance burns, its molecules and those of the oxygen in the air around it are set into motion, producing heat that unites the two groups of molecules in a rapid chemical reaction. In the combustion chamber of an engine cylinder, the gasoline vapor and oxygen in the air are ignited and burn. They combine, and the molecules begin to move about very rapidly, as the high temperatures of combustion are reached. This rapid movement of molecules provides the push on the piston to force it downward on the power stroke.

In the modern high compression gasoline engines the air-fuel mixture tends to ignite spontaneously or to explode instead of burning rather slowly and uniformly. The result is a knock, a ping, or a DETONATION. In detonation the spark from the spark plug starts the fuel mixture burning, and the flame spreads through the layers of the mixture, very quickly compressing and heating them. The last layers become so compressed and heated that they explode violently. The explosive pressure strikes the piston head and the walls of the cylinder, and causes the knock you hear in the engine. It is the fuel, not the engine that knocks. Besides being an annoying sound, persistent knocking results in engine overheating, loss of power, and increased fuel consumption. It causes severe shock to the spark plugs, pistons, connecting rods, and the crankshaft. To slowdown this burning rate of the fuel, a fuel of a higher octane rating must be used.

OCTANE RATING

The property of a fuel to resist detonation is called its antiknock or OCTANE rating. The octane rating is obtained by comparing the antiknock qualities of gasoline in a special test engine. In the test engine, the compression can be raised or lowered, and other engine controls are provided to make the engine knock or detonate. Two separate fuel chambers are also provided, with a rapid means of changing from the fuel being tested to the standard reference fuel. This reference fuel consists of a mixture of iso-octane, which has a very high antiknock rating, and heptane, which produces a pronounced knock. The octane rating of a gasoline being tested is the percentage by volume of iso-octane that must be mixed with normal heptane in order to match the knocking of the gasoline being tested. Octane numbers range from 50 to over 100. A number higher than 100 indicates that the antiknock value is greater than that of iso-octane.

The octane rating of gasoline can be raised in two ways: by mixing it with another fuel, or by treating it with a chemical. While alcohol and benzol can be added to improve the antiknock rating of a gasoline, their use will reduce the heat-producing value of the fuel. In this country, where alcohol and benzol are not commonly used for fuel, a chemical is added to gasoline to improve its octane rating.

The best chemical for this purpose is tetraethyl lead compound, which is added to the gasoline with ETHYL FLUID. In addition to the tetraethyl lead, ethyl fluid contains other chemicals that prevent lead deposits from forming within the engine. Lead oxide causes considerable corrosion.

The LEAD CONTENT of ethyl fluid is very poisonous. Ethyl gasoline should be used only for engine fuel and for no other purpose. It should never be used as a cleaning agent.

An engine which does not knock on a low octane fuel will not operate more efficiently by using a fuel of high octane rating. An engine which knocks on a given fuel should use one of a higher rating. If a higher octane fuel does not stop the knocking, some mechanical adjustments are probably necessary. Retarding the spark so that the engine will fire later may end knocking. However, an engine operating on retarded spark will use more fuel and will overheat. It may be less expensive to use a higher priced, high-octane gasoline with an advanced spark than to use a cheaper, low-octane gasoline with a retarded spark.

Besides a spark which is too advanced, a lean fuel mixture, a defective cooling system, or preignition also may be responsible for knocking. Preignition should not be confused with engine knock itself, which occurs late in the conbustion process, after the spark has occured. In preignition the air-fuel mixture begins to burn before the spark occurs. This condition may be cuased by an overheated exhaust valve head, hot spark plugs, or glowing pieces of carbon within the combustion chamber. In figure 4-2 you see the diagrammed course of the air-fuel mixture in the cylinder under circumstances of preignition and detonation, as well as in normal combustion.

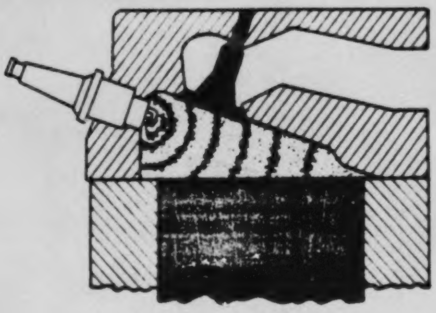
DIESEL FUEL

Diesel fuel is heavier than gasoline because it is obtained from the residue of the crude oil after the more volatile fuels have been removed. As with gasoline, the efficiency of a diesel fuel varies with the type of engine in which it is used. By distillation, cracking, and blending of several oils, a suitable diesel fuel can be obtained for almost all engine operating conditions. Slow speed diesels use a wide variety of heavy fuels; high speed diesel engines require a lighter fuel. Using a poor or an improper grade of fuel can cause hard starting, incomplete combustion, a smoky exhaust, and engine knocks.

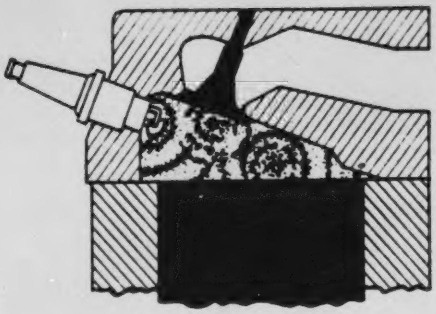
The properties to be considered in selecting a fuel for a diesel engine are VOLATILITY, CLEANLINESS, VISCOSITY, IGNITION QUALITY, AND ANTIKNOCK QUALITY.

VOLATILITY

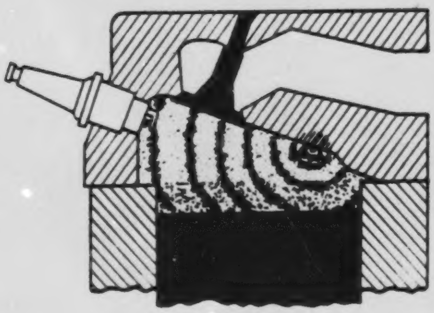
The volatility of a diesel fuel is measured by the 90 percent distillation temperature. This is the temperature at which 90 percent of a sample of the fuel has been distilled off. The lower this temperature, the higher the volatility of the fuel. In small diesel engines, a fuel of high volatility is more necessary than in large engines if there is to be low fuel consumption, low exhaust temperature, and little exhaust smoke.



NORMAL



DETONATION



PREIGNITION

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Figure 4-2.—Combustion process.

CLEANLINESS

Cleanliness of diesel fuel is very important. Fuel should not contain more than a trace of foreign substances; otherwise, fuel pump and injector difficulties will develop. Because it is heavier and more viscous, diesel fuel will hold dirt particles in suspension for longer periods than will gasoline. In the refining process, not all foreign matter can be removed, and harmful matter like dirt and water can get into the fuel while it is being handled. Water especially will rust an engine. Water will also cause hard starting and misfiring. Dirt will clog injectors and spray nozzles and may cause an engine to misfire or stop altogether.

JET PROPULSION FUELS (JP)

Primarily, jet propulsion fuels (JP) are for use in jet engines. However, some types of military equipment are being equipped with multifuel engines designed to use several different types of fuel including JP fuels.

VISCOSITY

The viscosity of fuel is the measure of its resistance to flow. Viscosity is expressed by the number of seconds required for a certain volume of fuel to flow through a hole of a certain diameter at a given temperature. The viscosity of diesel fuel must be low enough to flow freely at low temperatures, yet high enough to lubricate the pump and injector plungers properly and lessen the possibility of leakage at the pump plungers and dribbling at the injectors. Viscosity is measured by an instrument called the SAYBOLT VISCOSIMETER and is expressed in SAYBOLT SECONDS, UNIVERSAL (SSU).

IGNITION QUALITY

The ignition quality of a diesel fuel is its ability to ignite when it is injected into the compressed air within the engine cylinders. Ignition quality is measured by the CETANE RATING of the fuel. A cetane number is obtained by comparing the ignition quality of a given diesel fuel with that of a reference fuel of known cetane number in a test engine. This reference fuel is a mixture of alphamethylnapthalene, which is difficult to ignite alone, and cetane, which will ignite readily at temperatures and pressures comparable to those in the cylinders of a diesel engine. The cetane rating indicates the percentage of cetane in a reference fuel which will just match the ignition quality of the fuel being tested. The higher cetane numbers indicate more efficient fuels. The large slow diesels can use 30 cetane fuel, but the high speed diesels must use at least a 40 cetane fuel, while some require as high as a 60 cetane fuel.

The ignition quality of a diesel fuel depends also on its FLASH POINT and its FIRE POINT. The flash point is the temperature to which the fuel vapors must be heated to flash or ignite. The minimum flash point for diesel fuel is 150° F. A fuel having too low a flash point is danerous both to handle and to store.

The fire point is that temperature at which the fuel vapors will continue to burn after being ignited. It is usually 50 to 120 degrees higher than the flashpoint.

You will sometimes hear knocks in diesel engines. They are believed to be caused by the rapid burning of the fuel that accumulates in the delay period between injection and ignition. This delay is known as IGNITION LAG or IGNITION DELAY. When the fuel is injected into the cylinders, it must vaporize and be heated to the flash point to start combustion. The lag between vaporization and flash point depends upon the ignition quality of the fuel and the speed of the engine and its compression ratio. In high speed engines the delay varies from 0.0012 to 0.0018 of a second. Ignition lag decreases with the increase in engine speed because of a swifter air movement in the cylinders that makes the injected fuel heat better.

LUBRICANTS

A lubricant is a substance, usually an oil, used to reduce friction by preventing direct contact of moving surfaces with each other. The substance is pressed out into a thin film against which the moving parts rub.

The world lubricant comes from a Latin word meaning "slippery." The idea is that the film of oil gives to surfaces the slippery nature that prevents them moving against one another. This film is constantly renewed by additional oil supplied from the pressure pump to replace oil forced out by the movement of engine parts. The effect is that of two sheets or layers of oil sliding over each other. Thus friction between the two metal surfaces is reduced to a minimum. There are three types of kinetic friction: sliding friction, rolling friction, and fluid friction. Sliding friction exists when the surface of one solid body is moved across the surface of another solid body. Rolling friction exists when a curved body such as a cylinder or a sphere rolls upon a flat or curved surface. Fluid friction is the resistance to motion exhibited by a fluid.

Fluid friction exists because of the cohesion between particles of the fluid and the adhesion of fluid particles to the object or medium which is tending to move the fluid. If a paddle is used to stir a fluid, for example, the cohesive forces between the molecules of the fluid tend to hold the molecules together and thus prevent motion of the fluid. At the same time, the adhesive forces of the molecules of the fluid cause the fluid to adhere to the paddle and thus create friction between the paddle and the fluid. Cohesion is the molecular attraction between particles that tends to hold a substance or a body together; adhesion is the molecular attraction between particles that tends to cause unlike surfaces to stick together. From the point of view of lubrication, adhesion is the property of a lubricant that causes it to stick (or adhere) to the parts being lubricated; cohesion is the property which holds the lubricant together and enables it to resist breakdown under pressure.

Besides reducing friction and wear, lubricants act as COOLING AGENTS, absorbing heat from the surfaces over which they are spread. This is true particularly of engine oil, which carries heat to the engine sump, where it is dissipated. The water circulating through an oil cooler also helps to reduce this heat (not all engines have oil coolers).

Lubricants are also used as SEALING agents. They fill the tiny openings between moving parts, cushioning them against damage and distortion from extreme heat.

Lubricants are also important as CLEANING AGENTS. Any grit and dirt finding their way into the engine parts often are removed by the lubricants before damage can result. Foreign matter found in old oils and greases in the bottom of the crankcase is evidence of the cleansing quality of lubricants. Some lubricants have chemicals added to make them better cleaners.

The high temperatures, speeds, and cylinder pressures of modern engines have made necessary better grades of lubricating oils. To increase efficiency certain chemicals called ADDITIVES are put into oils. Additives are resistive agents which are used against oxidation and other kinds of metal deterioration. Oil which contains additives specifically designed to help clean the piston rings and other parts of the engine as it lubricates is known as DETERGENT OIL.

Lubrication is partly your job and partly the job of the Equipment Operator. The operator uses the oil and greases recommended for the job, but he may expect you to tell him which are the proper ones to use. It is therefore important for you to know why a certain fuel or lubricant is used and when to change to another type.

It is especially important for you to keep up with the latest developments in lubricants as presented in Navy and other technical publications. Your chief will tell you where you can get this information.

TYPES OF LUBRICANTS

Oils and greases are the two general types of lubricants. The modern high-speed gasoline or diesel engine must be properly lubricated with the proper grades and types of lubricating oils and greases. Present-day refining methods have produced lubricating oils and greases with certain special qualities. In engines operating at high speeds and temperatures, these oils do a better job than ordinary oils can do. Engines operating at low speeds or in cold weather may require an oil with other special qualities.

Greases are usually used where it is difficult to keep oil in place and where the lubricant is subjected to varying pressures. In some cases, greases are used when centrifugal forces tend to throw the lubricant from moving parts. This is especially true in differentials, gear boxes, and wheel bearings.

OILS

Lubricating oils serve four purposes: (1) prevent metal-to-metal contact in moving parts of mechanisms, (2) help carry heat away from the engine, (3) clean the engine parts as they are lubricated, and (4) form a seal between moving parts. Moving parts that do not have enough oil will melt, fuse, or seize after a very short period of engine operation. All gears and accessory drives, as well as other moving parts of the engine subject to friction, must be bathed in oil at all times.

We have seen that viscosity is the resistance of a liquid against flow. It is the most important property of a lubricating oil. A lubricant of high viscosity spreads very slowly. You have heard of car owners using a HEAVY oil in summer and changing to LIGHT oil in winter. The heavy oil used in summer becomes too sluggish in cold weather, while the light oil used in winter flows too easily in hot weather. An oil used in any engine must flow freely and have enough body to resist friction between moving engine parts; it must pass readily through all oil lines and spread effectively over all surfaces that require lubrication.

The temperature of an oil affects its viscosity. The higher the temperature, the lower the viscosity. On a cold morning, the high viscosity or stiffness of the lubricating oil makes an engine hard to turn over.

The viscosity of an oil is figured by the number of seconds which pass while a certain volume flows through a small opening or hole of a definite diameter at a given temperature. The greater the number of seconds, the higher the viscosity. The Society of Automotive Engineers (S.A.E.) has standardized a code of numbers to indicate the viscosity of lubricating oils. You will be using military symbols for these lubricating oils, which are expressed in four digits as indicated in Table 4-1. The last three digits indicate the viscosity in number of seconds required for 60 cubic centimeters of oil to flow through a standard opening at a given temperature. The first digit indicates the class and type of lubricating oil. You will use only the lubricant recommended for the particular engine which you service and lubricate. It is advisable to check with your chief from time to time for discontinued and new stocks and changed designations or specification numbers.

Oil is a mixture of many slightly different compounds, and therefore does not have a definite freezing point, but it does thicken as it cools. In order to determine the usefulness of an oil in cold weather, it is tested for its POUR POINT, which is the lowest temperature at which the oil will still flow. The pour point in which you will be interested is the lowest temperature at which the oil on the cylinder walls and bearings will permit the engine to be turned.

While the flash point and the fire point of an oil do no affect its lubricating qualities, they are useful in determining the amount of volatile fluids or compounds in the oil. As you learned concerning diesel oil, the flash point is the temperature at which vapors will ignite, but not sustain a flame. The flash point of a lubricating oil for your entire engine must range from 300° F to 500° F to keep the oil from vaporizing too readily in the crankcase and to make it withstand the heat of the engine. It is used also to determine the fire hazard in shipping and storing the lubricant.

Again, as you previously learned, the fire point is the temperature at which vapors given off continued to burn when ignited. Both the flash point and the fire point must be taken into consideration in the blending of an oil of proper viscosity for the type and condition of the engine in which it is to be used.

DILUTION AND CONTAMINATION OF OIL

From the day that fresh oil is put into the engine crankcase, it gradually begins to lose its effectiveness because of dilution and contamination from engine operation. Gasoline or diesel fuel may dribble into the crankcase oil. Water and sludge also may accumulate. Carbon, gum acids, and dust in the air entering the engine (in the air-fuel mixture) all reduce the effectiveness of any lubricant. It is because of this accumulation of foreign matter that manufacturers recommend regular oil changes, and that regular lubrication is so important in preventive maintenance.

Greases are compounds of oil and soap. The soaps used are not ordinary laundry soaps but animal fats mixed with certain chemicals. The chief purpose of the soap is to provide a body or carrier for the oil that actually does the lubricating.

Grease is used where oil is impractical or unsatisfactory due to centrifugal forces, loads, temperatures or exposure. For instance, it maintains a film at high engine speed and temperature, or when the equipment is idle for long periods of time.

The chemicals in the grease classify it for a particular purpose or use. CHASSIS GREASES have a lime, sodium, or an aluminum soap base. Of the three bases, the lime and the aluminum are the most water resistant, while the aluminum is the most heat resistant. Chassis greases are distinguished by their shiny, transparent appearance, and are used as a pressure gun lubricant for chassis, U-joints, track rollers, and low temperature ball bearings.

CUP GREASE, or WATER-PUMP GREASE, is a lime-base grease to which water or moisture is added to keep the soap from separating from the oil. The moisture gives the grease a somewhat cloudy appearance, and it will evaporate at a temperature equal to that of boiling water. Lime base greases are not recommended for parts subjected to high temperature. These greases are recommended when moisture resistance is required, and are satisfactory for water pumps and marine stuffing boxes.

WHEEL BEARING or FIBROUS GREASES have a sodium or mixed soap base. These greases only appear fibrous, for there are no actual fibers in them. They are recommended for wheel bearings because they stick or cling

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Table 4-1.—Military and Commercial Designations for Gear and Lubricating Oils used in Equipment Maintenance

General Description	Military Designation and Specification Number	Typical Commercial Designation	Uses
Gear oil. . . . . Containing extreme pressure (EP) additives to maintain lubrication under extreme pressure conditions.	Lubricant, Gear, Universal, MIL-L-10324. FSN 9150-259-5443.	E.P. Hypoid Gear Lubricant. Universal Gear Lubricant for very cold climates.	For all gear lubrication including transmission, differentials, hypoid gears, tractor final drives, and steering gear mechanisms in cold climates when the prevailing temperature is below 0° F.
Gear oil. . . . . Containing extreme pressure (EP) additives to maintain lubrication under extreme pressure conditions.	Lubricant, Gear, Universal, MIL-L-2105. FSN 9150-577-5842.	SAE 80 EP Hypoid or Universal Gear Lubricant. MA 1327	As above except that it is an SAE 80 gear lubricant for use where the prevailing temperature is between 0° and 32° F.
	FSN 9150-577-5845.	SAE 90 EP Hypoid or Universal Gear Lubricant. MA 1328	As above except that it is an SAE 90 gear lubricant for use where the prevailing temperature is above 0° F.
Mineral Gear Oil, SAE 140. NO ADDITIVES.	Military Symbol 5190. MIL-L-2105. FSN 9150-577-5848.	SAE 140 Mineral Gear Oil. Steam Cylinder Oil. MA 1329	For use in tractor transmissions and final drives only in tropical areas. There are no extreme pressure chemical additives in this oil. DO NOT mix with extreme pressure lubricants. DO NOT use in hypoid gear drives such as truck or passenger vehicle differentials.
SAE-10 Heavy Duty Lubricating Oil.	Military Symbol 9110. FSN 9150-231-9039.	Gasoline and Diesel Engine Oil, SAE-10 and SAE-10 W Grades.	For crankcase lubrication in both gasoline and diesel engines requiring an SAE-10 or SAE-10 W oil and for general purpose lubrication.
SAE-20 Heavy Duty Lubricating Oil.	Military Symbol 9170. FSN 9150-231-6651.	Gasoline and Diesel Engine Oil, SAE-20 Grade.	For crankcase lubrication in both gasoline and diesel engines requiring an SAE-20 oil and for general purpose lubrication.
SAE-30 Heavy Duty Lubricating Oil.	Military Symbol 9250. FSN 9150-231-6655.	Gasoline and Diesel Engine Oil, SAE-30 Grade. MB 1702	For crankcase lubrication in both gasoline and diesel engines requiring an SAE-30 oil and for general purpose lubrication.
SAE-40 Heavy Duty Lubricating Oil.	Military Symbol 9370. FSN 9150-912-9552.	Gasoline and Diesel Engine Oil, SAE-40 Grade.	For crankcase lubrication in both gasoline and diesel engines requiring an SAE-40 oil and for general purpose lubrication.

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Table 4-1.-Military and Commercial Designations for Gear and Lubricating Oils used in Equipment Maintenance—continued.

General Description	Military Designation and Specification Number	Typical Commercial Designation	Uses
SAE-50 Heavy Duty Lubricating Oil.	Military Symbol 9500. FSN 1950-231-9043.	Gasoline and Diesel Engine Oil, SAE-50 Grade. MB 1722	For crankcase lubrication in both gasoline and diesel engines requiring an SAE-50 oil and for general purpose lubrication.
Medium VI Mineral Oil SAE-50. No additives.	Military Symbol 3100. FSN 9150-223-8893.	Mineral Oil SAE-50	For lubrication of certain 2-stroke cycle gasoline engines where prescribed. Mixed with fuel in specified proportions such as outboard motorboat engines. For general purpose lubrication.
Hydraulic Transmission Fluid, Type C-1	EO—Series 3 or MIL-L-45199A. Grade 10. FSN 9150-680-1103.	Lubricating Oil High Output.	For hydraulic systems and certain transmission and converter units as prescribed by the manufacturer.

to parts. Since they are not water resistant, they can be used only on protected parts.

CABLE GREASE (wire rope and exposed gear grease) is a sticky black oil used to lubricate chains and wire ropes.

The black, tarlike sticky mass called CRATER COMPOUND is used to grease sliding surfaces and exposed gears on heavy duty construction equipment. It is applied by hand or with a brush and cannot be squeezed from between the gear teeth or the sliding surfaces. You will find a can of this grease on nearly every shovel or crane used by the Navy.

If your shop has a supply of ALL-PURPOSE (GAA - Grease, Automotive and Artillery) grease, your chief may direct you to use it, instead of the various greases just mentioned.

Some form of dry lubricant such as GRAPHITE POWDER is available in the shop, to lubricate small parts and door locks, where a liquid would run off or otherwise be undesirable.

Petroleum refiners have developed greases to meet special lubrication requirements of modern machinery and equipment. Table 4-2 lists and describes the kinds of greases and their uses for proper maintenance.

HANDLING PETROLEUM PRODUCTS

When handling petroleum products, care must be taken to ensure they do not become contaminated with foreign matter. Since all petroleum products will burn, fire is an ever present hazard. The degree of fire hazard increases as the volatility of the product increases.

Inhaling gasoline vapors may cause headaches, dizziness, nausea, or even unconsciousness. If any of these symptoms are noticed among men handling gasoline or working in an area where gasoline has been spilled, the men should leave the area at once. If anyone has been overcome, he should receive immediate medical attention.

Gasoline may cause severe burns if allowed to remain in contact with the skin, particularly under soaked clothing or gloves. Clothing or shoes through which gasoline has soaked should

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Table 4-2.—Military and Commercial Designation for Greases used in Equipment Maintenance

General Description	Military Designation and Specification Number	Typical Commercial Designation	Uses
Grease, Chasis—Lime, soda or aluminum soap base grease.	Lubricant, General Mil-G-10924 Mil Sym GAA FSN 9150-530-7369	Chassis Grease, Cup Grease, Pressure Gun Grease, No. 1—Soft.	For general use as a pressure gun lubricant, particularly chassis, universal joints, track rollers, ball bearings operating below 150° F. Lime and aluminum soap base grease types are water resistant.
Grease, Wheel Bearing Soda or mixed soap base grease.	Lubricant, General Purpose, No. 2 (Wheel-Bearing-Chassis Lubricant—WB). VV-G-632 Type B, Grade 2. FSN 9150-531-6971.	Wheel Bearing Grease, No. 2—Medium.	For wheel bearings, ball bearings, and as a pressure gun lubricant when operating temperatures are expected to be above 150° F. DO NOT USE TO GREASE UNIVERSAL JOINTS OR OTHER PARTS HAVING NEEDLE BEARINGS. Not water resistant.
Grease, Ball and Roller Bearing Soda or mixed soap base grease.	Lubricant, Ball and Roller Bearing. Mil-G-18709. FSN 9150-249-0908.	Ball and Roller Bearing Grease, BRB.	BRB and G-18709 suitable for ball and roller bearing lubrication, especially in electric motors and generators and clutch pilot bearings. Not water resistant.
Grease—Water Pump Lime soap base grease.	Lubricant, Water-Pump, No. 4. VV-G-632 Type A, Grade 4. FSN 9150-235-5504.	Water-Pump Grease, No. 4—Hard.	For gland type water-pumps of some engines not equipped with factory lubricated and sealed water pumps. Very water resistant.
Lubricant, Exposed Gear, Chain, and Wire Rope Sticky, viscous, black, residual oil.	Lubricant, Chain and Wire Rope. Mil-G-18458. FSN 9150-530-6814.	Exposed Gear Chain and Wire Rope Lubricant. Gear Grease. Wire Rope Grease No. 2.	For greasing cable, open gears or any open mechanism requiring rough lubrication. Usually heated before applying. Grade B is intended for use in temperate or warm weather and is suitable for open-air or under-water conditions. Not for cables in contact with earth.
		As above, except that it is No. 3 or heavy duty type.	As above except that Grade C is for use in hot weather or for hard service and is suitable for open-air or under-water conditions.

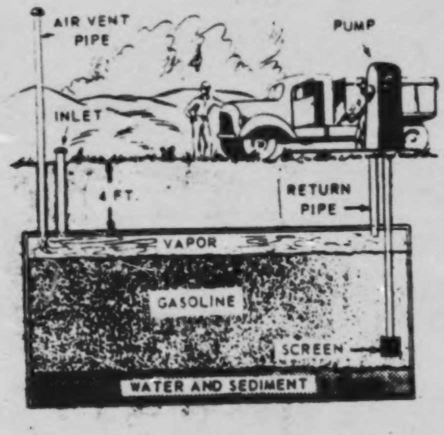

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Figure 4-3.—Underground gasoline storage tank.

be removed at once. Gasoline should be washed from the skin with soap and water. Repeated contact with gasoline removes the protective oils from the skin and causes drying, roughening, chapping, and cracking and, in some cases, infections of the skin. Gloves should be worn as protection by persons handling petroleum products.

If gasoline gets into a person's eyes, first aid should be given immediately. Olive oil, castor oil, or mineral oil may be applied, and medical attention should be secured.

If a person swallows gasoline by accident, first aid should be given immediately. Giving the victim warm salty water to induce vomiting is an effective aid. Medical attention should be secured promptly.

Slipping and falling are common accidents which occur when handling petroleum products. This danger is particularly grave while climbing to and from loading racks, storage tanks, or stacks of drums or cans. Tools, pieces of lumber, and other objects should not be left lying where they may cause accidents.

On a hot day, gasoline vapors mixed with air may be flammable for a distance of 20 feet from an open container. By using underground tanks there will be less chance of a fire or an explosion, and less gas will be lost by evaporation. Areas near gasoline storage tanks should ALWAYS BE WELL POSTED WITH WARNING SIGNS.

Gasoline storage tanks should be placed underground and covered with at least 3 or 4 feet of earth. The tanks must be equipped with vent pipes which extend well above the ground so that the vapors may spread and disappear. (See fig. 4-3.)

Diesel fuel is not as volatile, flammable, nor as dangerous to handle as gasoline. But it will burn, and in closed unventilated places, diesel vapors can be explosive.

Diesel fuel is generally not stored in the same way as gasoline. Figure 4-4 shows a typical diesel fuel storage tank. The tank is generally placed above ground on a raised platform. The platform should be high enough to permit the fueling of equipment from the tank by gravity flow. The tank must be provided with an air vent at the top and a drain cock at the lowest point. The outlet for the fuel should be at least 6 inches from the bottom of the tank, so that any water and dirt which have accumulated and settled in the bottom will not be drained into the fuel tanks of the equipment being serviced. The water and sediment that collect in the bottom of the tanks should be drained off daily. When you fill a diesel fuel storage tank, remember to leave enough room for expansion of the fuel.

Lubricating oil and greases are furnished in various sizes of containers. More lubricant is wasted because it has become contaminated than for any other cause. All containers should be clearly marked as to their contents and dates received. The lubricants that have been in stock the longest should be used first. Make sure that all openings of lubricant containers are properly secured. This will decrease the chances of lubricants becoming contaminated.

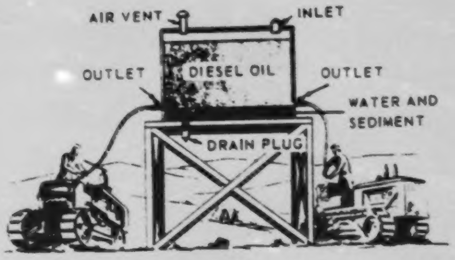

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Figure 4-4.—Storage tank for diesel fuel.

CHAPTER 8

THE DIESEL ENGINE

In previous chapters, we discussed the factors necessary for an internal-combustion engine to operate efficiently. We saw that air, and fuel, must be supplied in the proper mixture and the proper time before any engine can operate.

In this chapter, we shall take up the diesel engine. The first part of the chapter discusses similarities and differences between gasoline and diesel engines. The rest of the chapter describes general factors which apply mainly to diesels.

GASOLINE VS DIESEL ENGINES

Like the gasoline engine, the diesel engine is an internal combustion engine using either a 2- or 4-stroke cycle (discussed in ch. 3). Power is obtained by the burning or combustion of fuel within the engine cylinders. There must, of course, be some means of igniting the air and fuel mixture. As you read in previous chapters, an electric spark from the ignition system is used to ignite the mixture of gasoline and air in a gasoline engine. The ignition system is necessary because of the rather low compression ratio in the gasoline engine. This ratio ranges from 6:1 to about 10:1, and the compression pressure ranges from 110 to about 150 pounds per square inch (psi). The compression temperature within the cylinders ranges from 220° F to 300° F (2 degree rise in temperature for every psi rise in pressure), which is not high enough to ingnite the gasoline and air mixture.

DIESEL COMPRESSION AND IGNITION

In most diesel engines the compression ratio ranges from 14:1 to about 19:1, and the compression pressure ranges from 400 to 600 psi. The compression temperature varies from 800° F to 1200° F. This compression temperature is high enough to ignite the finely atomized diesel fuel which is injected into the combustion chamber when the piston is near top dead center of the compression stroke. The diesel engine is, therefore, known as a COMPRESSION-IGNITION engine, while the gasoline engine is a SPARK-IGNITION engine.

PRINCIPLES OF OPERATION

In principle of operation, the main differences between the gasoline engine and the diesel engine are the methods of getting the fuel into the cylinders, and of igniting the air-fuel mixtures. You learned that in the gasoline engine the air and gasoline are mixed together in the carburetor. The mixture then passes through the intake manifold where it starts to vaporize. Then the mixture enters the cylinder through the intake valve where it is completely vaporized by the heat of compression as the piston moves upward on the compression stroke. When the piston reaches near top dead center, the mixture is ignited by a spark from the spark plug.

The diesel engine does not use spark plugs nor a carburetor. On the intake stroke, only fresh air is drawn into the cylinders through the intake valve and manifold. On the compression stroke, the air is compressed to a pressure between 400 and 600 psi, and temperature in the cylinder rises to a point between 800° and 1200° F. At the proper time, the diesel fuel is injected into the cylinder by a fuel injection system, which usually consists of a pump, fuel lines, and injector or nozzle. When the fuel oil enters the cylinder it will ignite. Figure 8-1 shows the comparison of the four strokes of a 4-cycle diesel and a 4-cycle gasoline engine.

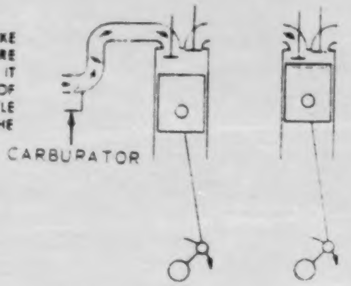
The speed of a diesel engine is controlled by the amount of fuel that is injected into the cylinders; in a gasoline engine the speed of the

GASOLINE

DIESEL

INTAKE STROKE

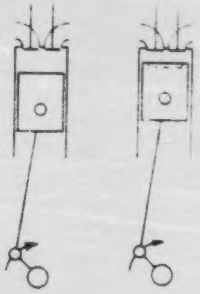
ON DOWNWARD STROKE OF PISTON, INTAKE VALVE OPENS AND ATMOSPHERIC PRESSURE FORCES AIR THROUGH CARBURETOR WHERE IT PICKS UP A METERED COMBUSTIBLE CHARGE OF FUEL. THE MIXTURE GOES PAST THE THROTTLE VALVE INTO CYLINDER SPACE VACATED BY THE PISTON



ON DOWNWARD STROKE OF PISTON, INTAKE VALVE OPENS AND ATMOSPHERIC PRESSURE FORCES PURE AIR INTO THE CYLINDER SPACE VACATED BY THE PISTON. THERE BEING NO CARBURETOR OR THROTTLE VALVE. CYLINDER FILLS WITH SAME QUANTITY OF AIR REGARDLESS OF LOAD ON THE ENGINE

COMPRESSION STROKE

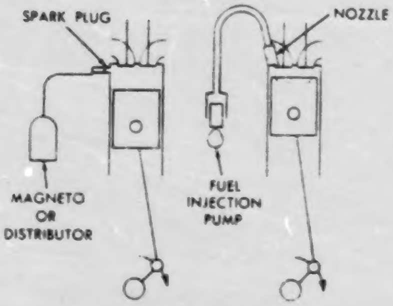
ON UPSTROKE OF PISTON, VALVES ARE CLOSED AND MIXTURE IS COMPRESSED, USUALLY FROM 110 TO 150 PSI, DEPENDING ON COMPRESSION RATIO OF ENGINE



ON UPSTROKE OF PISTON, VALVES ARE CLOSED AND AIR IS COMPRESSED TO APPROXIMATELY 400 TO 600 PSI

POWER STROKE

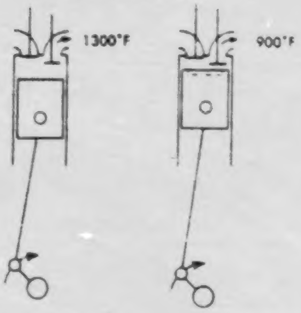
COMPRESSED FUEL-AIR MIXTURE IS IGNITED BY ELECTRIC SPARK. HEAT OF COMBUSTION CAUSES FORCEFUL EXPANSION OF CYLINDER GASES AGAINST PISTON, RESULTING IN POWER STROKE



HIGH COMPRESSION PRODUCES HIGH TEMPERATURE FOR SPONTANEOUS IGNITION OF FUEL INJECTED NEAR END OF COMPRESSION STROKE. HEAT OF COMBUSTION EXPANDS CYLINDER GASES AGAINST PISTON, RESULTING IN POWER STROKE

EXHAUST STROKE

UPSTROKE OF PISTON WITH EXHAUST VALVE OPEN FORCES BURNED GASES OUT, MAKING READY FOR ANOTHER INTAKE STROKE.



UPSTROKE OF PISTON WITH EXHAUST VALVE OPEN FORCES BURNED GASES OUT, MAKING READY FOR ANOTHER INTAKE STROKE

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Figure 8-1.–Comparison of sequence of events in diesel and gasoline 4-cycle engines.

engine is controlled by the amount of air admitted into the carburetor.

Mechanically, the diesel engine is similar to the gasoline engine. The intake, compression, power, and exhaust strokes occur in the same order. The arrangement of the pistons, connecting rods, crankshaft, and engine valves are about the same. The diesel engine is also classified as INLINE or V-TYPE.

ADVANTAGES AND DISADVANTAGES OF THE DIESEL

The main advantages of diesel engines as compared with gasoline engines are high power per pound of fuel (particularly with present day high speed engines), high reliability in operation, low fuel consumption per horsepower per hour, and reduced fire hazard.

The disadvantages of the diesel engine are the high cost of manufacture, the heavier construction necessary to withstand the high compression pressures, and difficulty in starting because of high compression pressure.

At present there are relatively few diesel engine powered passenger automobiles, but the use of the diesel engine for small load and passenger carrying vehicles is becoming more practical with the development of improved, lightweight, high speed automotive diesel engines.

FUEL SUPPLY PUMP

Fuel injection pumps must be supplied with fuel oil under pressure because they have insufficient suction ability. All diesel injection systems require a supply pump to transfer fuel from the supply tank, through the filters and lines to the injection pumps. Supply pumps in use on diesel engines today are the GEAR, VANE, and PLUNGER type pump.

GEAR PUMP

The simple GEAR PUMP, figure 8-2, has two spur gears which mesh together; one is the driving gear, and the other is the driven gear. Clearances between the gear teeth and the casing and between the gear faces and the casing are only a few thousandths of an inch. When the gears turn, liquid in the spaces between the unmeshed teeth, at the suction side of the pump, is carried by the teeth towards the sides. Then the liquid is trapped between the tooth pockets and the casing, and carried through to the discharge side of the pump. The liquid entering the discharge side cannot return to the suction side because the meshing teeth at the center force the liquid out of the tooth pockets.

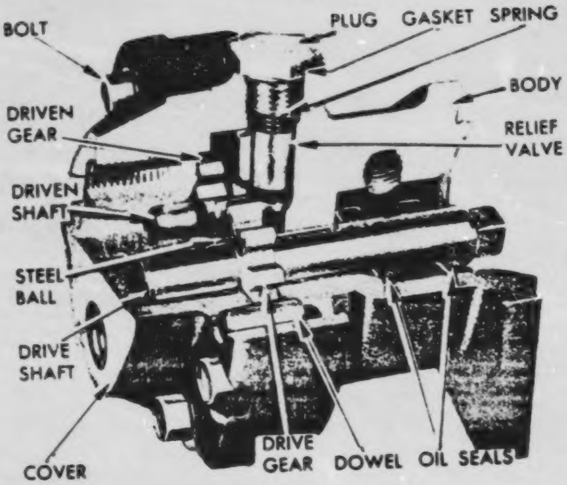

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Figure 8-2.—Typical gear fuel pump assembly.

VANE PUMP

In the vane-type pump (figs. 8-3 and 8-4), a steel rotor and shaft, one end supported in the pump mounting flange and the other end in the pump cover, revolve in the body, the bore of which is eccentric to the rotor. Two sliding vanes are placed 180 degrees apart in slots in the rotor, and are pressed against the body bore by springs in the slots. When the shaft is rotated, the vanes pick up fuel at the inlet port and carry it around the body to the outlet side, where the fuel is discharged. Pressure is produced by the wedging action of the fuel as it is forced toward the outlet port by the vane. A spring-loaded relief valve is provided in the cover of the pump, connecting the inlet and outlet ports. This valve opens at a pressure of approximately 55 psi. Its purpose is to relieve excessive pump pressure which will build up if fuel lines or filters become clogged. When the valve opens, fuel passes from the discharge side (pressure side) to the suction side of the pump.

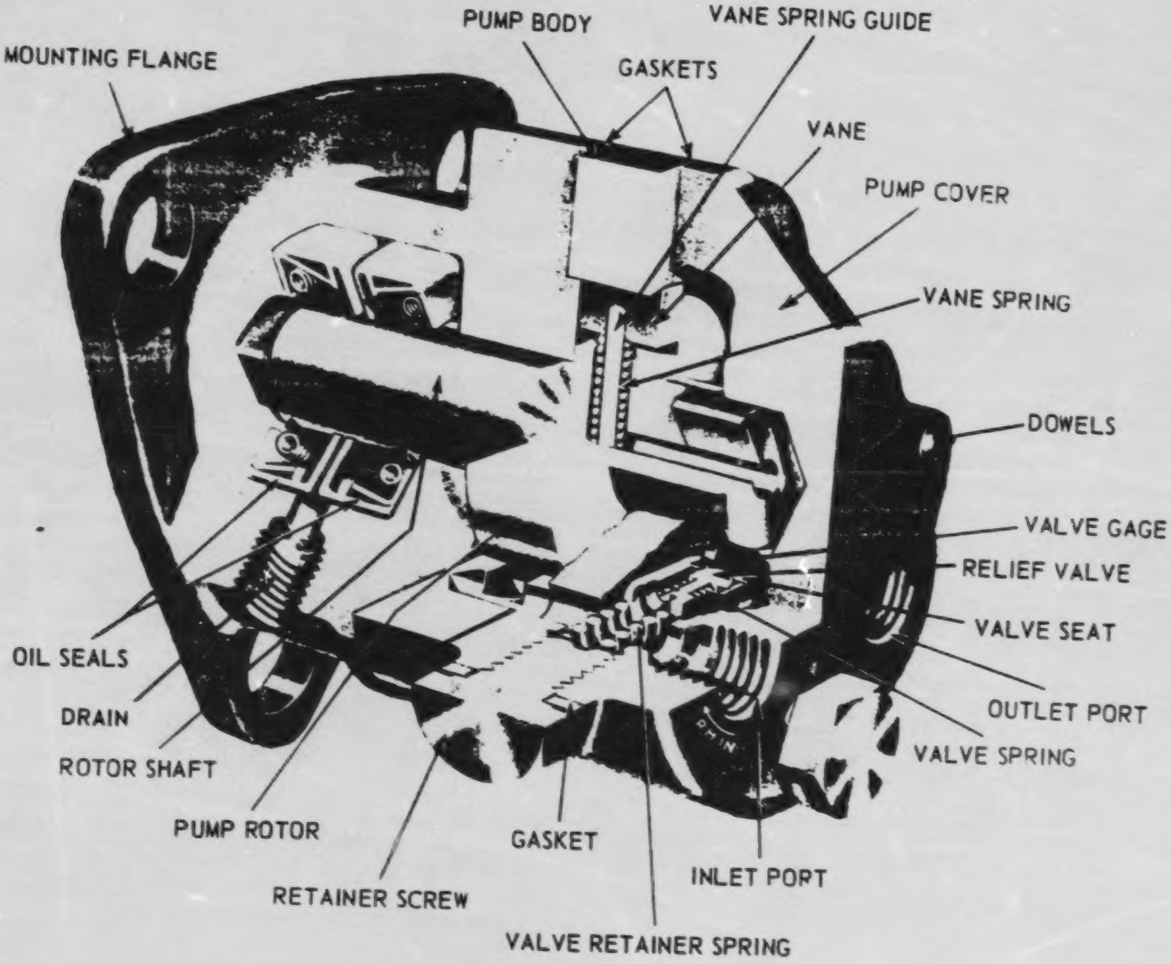
MOUNTING FLANGE
PUMP BODY
VANE SPRING GUIDE
GASKETS
VANE
PUMP COVER
VANE SPRING
DOWELS
VALVE GAGE
RELIEF VALVE
VALVE SEAT
OUTLET PORT
VALVE SPRING
OIL SEALS
DRAIN
ROTOR SHAFT
PUMP ROTOR
GASKET
INLET PORT
RETAINER SCREW
VALVE RETAINER SPRING

Figure 8-3.-Cutaway view of vane-type fuel pump

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FUEL INJECTION AND COMBUSTION

Diesel fuel injection systems must accomplish five particular functions: Meter, inject, time, atomize, and create pressure. A description of these functions follows:

1. METER-Accurately measure the amount of fuel to be injected.
2. INJECT-Force and distribute the fuel into the combustion chamber.
3. TIME-Injection of the fuel must start and stop at the proper time.
4. ATOMIZE-Break the fuel up into fine particles.
5. CREATE PRESSURE-Create the necessary high pressure for injection.

You can remember these functions by the initials, MITAC. All five of these functions are necessary for complete and efficient combustion.

METERING

Accurate metering or measuring of the fuel means that, for the same fuel control setting,

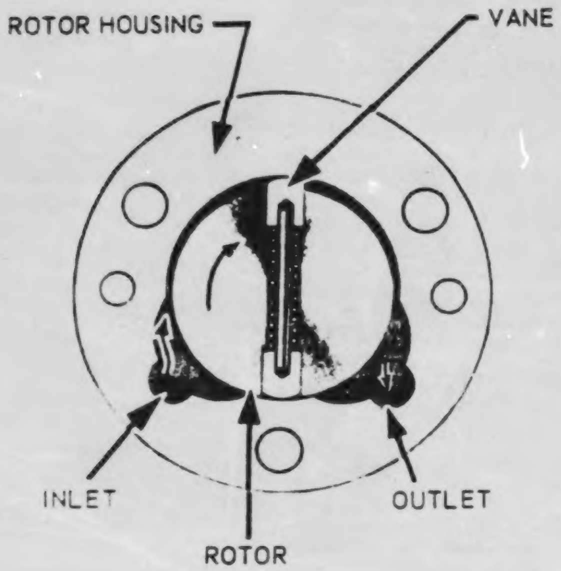

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Figure 8-4.—Vanes and rotor in housing of a vane-type fuel pump.

the same quantity of fuel must be delivered to each cylinder for each power stroke of the engine. Only in this way can the engine operate at uniform speed with a uniform power output. Smooth engine operation and an even distribution of the load between the cylinders depend upon the same volume of the fuel being admitted to a particular cylinder each time it fires; and upon equal volumes of fuel being delivered to all cylinders of the engine.

INJECTION CONTROL

A fuel system must also control the rate of injection. The rate at which fuel is injected determines the rate of combustion. The rate of injection at the start should be low enough that excessive fuel does not accumulate in the cylinder during the initial ignition delay (before combustion begins). Injection should proceed at such a rate that the rise in combustion pressure is not too great, yet the rate of injection must be such that fuel is introduced as rapidly as possible in order to obtain complete combustion. An incorrect rate of injection affects engine operation in the same way as improper timing. When the rate of injection is too high, the results are similar to those caused by a too early injection; when the rate is too low, the results are similar to those caused by a too late injection.

TIMING

In addition to measuring the amount of fuel injected, the system must properly time injection to ensure efficient combustion so that maximum energy can be obtained from the fuel. When the fuel is injected too early in the cycle, ignition may be delayed because the temperature of the air at this point is not high enough. An excessive delay, on the other hand, gives rough and noisy operation of the engine, and also permits some fuel to be lost due to the wetting of the cylinder walls and piston head. This, in turn, results in poor fuel economy, high exhaust gas temperature, and smoke in the exhaust. When fuel is injected too late in the cycle, all the fuel will not be burned until the piston has traveled well past top center. When this happens, the engine does not develop its maximum power, the exhaust is smoky, and the fuel consumption is high.

ATOMIZATION OF FUEL

As used in connection with fuel injection, atomization means the breaking up of the fuel, as it enters the cylinder, into small particles which form a mist-like spray. Atomization of the fuel must meet the requirements of the type of combustion chamber in use. Some chambers require very fine atomization; others function with coarser atomization. (Because of the design of the multifuel hypercycle chamber, discussed later in this chapter, atomization is accomplished differently in chambers so designed.) Proper atomization makes it easier to start the burning process, and ensures that each minute particle of fuel is surrounded by particles of oxygen with which it can combine.

Atomization is generally obtained when the liquid fuel, under high pressure, passes through the small opening (or openings), in the injector or nozzle. As the fuel enters the combustion space, high velocity is developed because the pressure in the cylinder is lower than the fuel pressure. The created friction, resulting from the fuel passing through the air at high velocity, causes the fuel to break up into small particles.

CREATING PRESSURE

A fuel injection system must increase the pressure of the fuel enough to overcome compression pressures and to ensure proper dispersion of the fuel injected into the combustion space. Proper dispersion is essential if the fuel is to mix thoroughly with the air and burn efficiently. While pressure is a chief contributing factor, the dispersion of the fuel is influenced, in part, by atomization and penetration of the fuel, (Penetration is the distance through which the fuel particles are carried by the motion given them as they leave the injector or nozzle.)

If the atomization process reduces the size of the fuel particles too much they will lack penetration. Too little penetration results in the small particles of fuel igniting before they have been properly distributed, or dispersed in the combustion space. Since penetration and atomization tend to oppose each other, a compromise in the degree of each is necessary in the design of fuel injection equipment, particularly if uniform distribution of fuel within the combustion chamber is to be obtained.

AIR INTAKE SYSTEM

You learned that much of the information dealing with parts and systems of the diesel engine also applies to the gasoline engine. The air intake system is no exception. However, the intake event in the cylce of operation of a gasoline engine includes the admission of air and fuel to the cylinder as a mixture. For this reason the intake system of a gasoline engine differs, in some respects, from that of a diesel engine.

In some 4 -stroke cycle diesel engines, air is forced by atmospheric pressure into the cylinder through valves to satisfy the difference in air pressure created by the pistons. However, in most 2-cycle and many supercharged 4-cycle engines, air is forced into the cylinder by a blower (supercharger) or by a turbocharger. The turbocharger is usually an exhaust-driven centrifugal type blower.

The main job of the blower, supercharger, or turbocharger, is to supply the cylinder with fresh air for combustion so the engine can burn more fuel and develop more horsepower than if it were fed through valves by atmospheric pressure. A blower normally consists of two hollow three-lobed rotors enclosed in a housing on the side of the cylinder block. They revolve without touching each other, but with very close clearance. At maximum engine speed the blower is capable of supplying a continuous discharge of fresh air at a pressure of 7 psi.

Figure 8-5 illustrates how the air sweeps into the cylinder through the intake ports as they are uncovered by the downward stroke of the piston. This sweeping action forces out the burned gases through the exhaust valve openings and helps to cool the internal parts of the engine, particularly the exhaust valves. The intake ports are angled to give the incoming air a circular motion (turbulence) during the compression stroke to improve combustion.

As you know, all diesel construction equipment used in road-building, excavating, construction of landing strips, and similar construction activities constantly stirs up particles of dirt and dust. These particles cause internal damage if they enter the engine as air enters. Therefore, diesel engines are equipped with air cleaners or filters to eliminate dust and dirt particles. There are two distinct types of air cleaners used on diesels: the DRY type and the OIL-BATH or WET type.

The dry-type air cleaner draws the air through a cleaning element, which may consist of cotton fabric, wire screens (specially wound copper crimp), or metal wool saturated with oil. The cleaning element collects the dust and other abrasive particles from the air before entering the engine. The hollow housing supporting the cleaning element also serves as a silencer to lessen the whining noise of the air entering the air cleaner.

The OIL-BATH or WET-TYPE air cleaner is similar to the dry-type cleaner. The main difference is that the wet type contains an oil reservoir in the air cleaner bowl, and the air is directed downward into the oil bath, where most of the harmful particles are removed. The air then continues upward through the cleaning element (metal wool), which removes the finer harmful particles not removed by the oil. From this point, the filtered air continues down the central duct into the blower.

FUEL FILTERS

Fuel filters are built into the fuel supply systems of diesel engines to filter any abrasive impurities that may be in the fuel. These impurities may have been difficult to eliminate during the process of refining, or they may enter the fuel tank through careless refueling. Whatever the source, these impurities must be removed to protect the closely fitted parts in the pumps and nozzles.

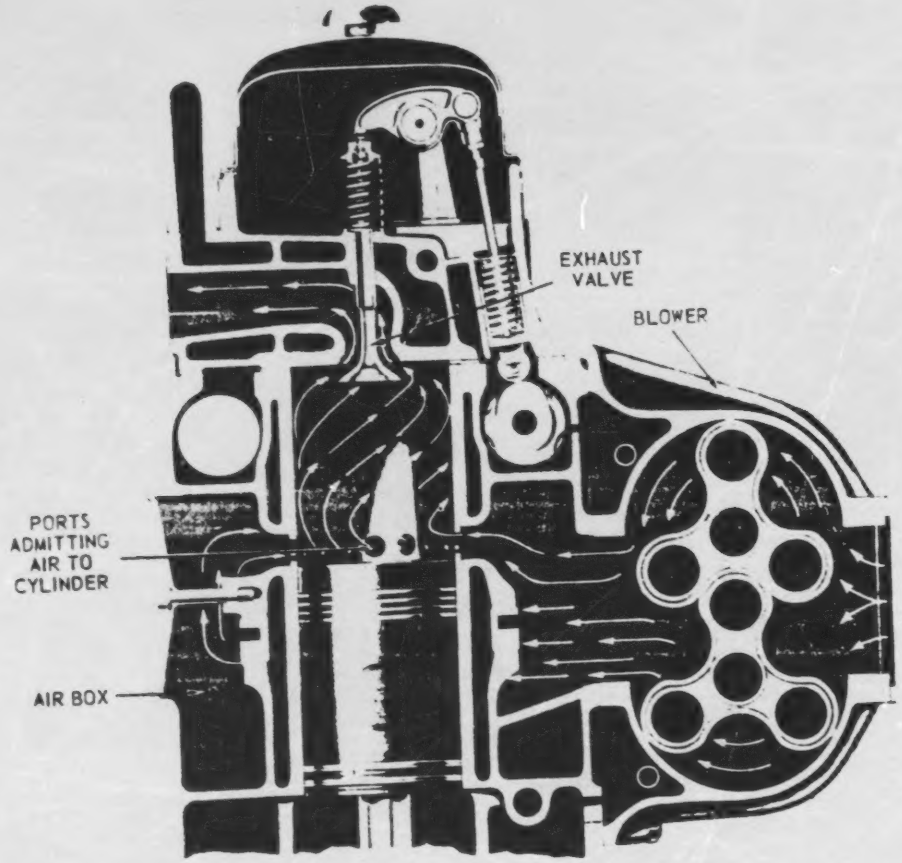

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Figure 8-5.—Air intake system through blower and engine.

Most diesel engines have two filters in the fuel supply system. The primary (coarse) filter is usually located between the supply tank and the fuel supply pump, and the secondary (fine) filter between the fuel supply pump and the injection pump. Additional filtering elements are frequently installed between the injection pump and the nozzle.

Diesel fuel oil filters are referred to as FULL-FLOW filters, since all the fuel must pass through the filters before reaching the injection pumps. Filters must be inspected regularly and cleaned or replaced, if their maximum efficiency is to be maintained. ALL METAL-DISK filters and some CLOTH-BAG filters are cleanable, but most cloth or fabric elements must be replaced when they become dirty.

METAL-DISK FILTER

The metal-disk filter shown in figure 8-6 is made of a series of laminated disks placed within a large bowl which acts as a settling chamber for the fuel and encloses the disks or strainer assembly. Fuel enters the filter at the top inlet connection and, flowing down, goes between the disks, and then up a central passage to the outlet connection at the top. Dirt and foreign matter cannot pass between the disks and are deposited at the outer rim. The clearance between the disks (0.003 inch) is small enough to prevent the passage of water. This is possible because water, when present in gasoline or oil, forms small globules that are too large to pass between the disks. The filter shown in figure 8-6 is the same as the one mentioned above except that a cleaning knife is added. Solids larger than 0.005 inch remain on the outside of the element, and the cleaning knife scrapes these deposits off the filtering disks. The solids fall to the bottom of the filter housing, where they can be removed through the drain plug hole. A ball relief valve in the filter cover enables the fuel oil to bypass the filter element if the disks become clogged. A diesel fuel oil filter usually has an air vent for releasing any air which might accumulate in the filter during engine operation.

FABRIC FILTER

Fabric filters, because of their greater filtering qualities, are used principally as main filters for protecting the fuel injection pump. Many fuel oil filters now in use require changing the filtering element. One type that can be cleaned is the bag type shown in figure 8-7. The filtering medium is a large bag of close, evenly-woven, lintless, acid-resisting material. Many fuel systems now use microporous paper fuel filters which are replaceable.

COMBUSTION CHAMBER DESIGN

Several types of combustion chambers are used in modern diesel engines. They are designed to create turbulence in the cylinder in

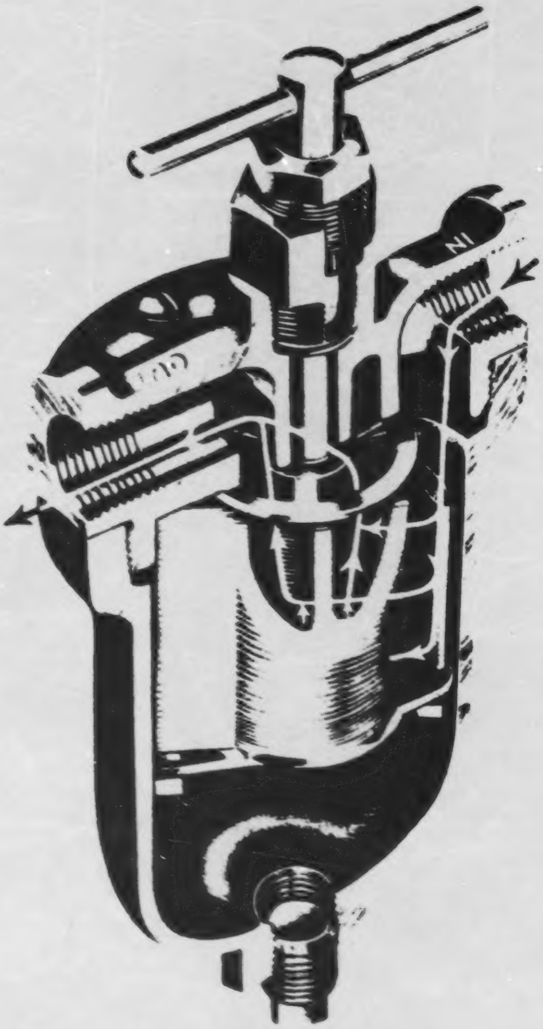

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Figure 8-6.—Metal-disk fuel filter.

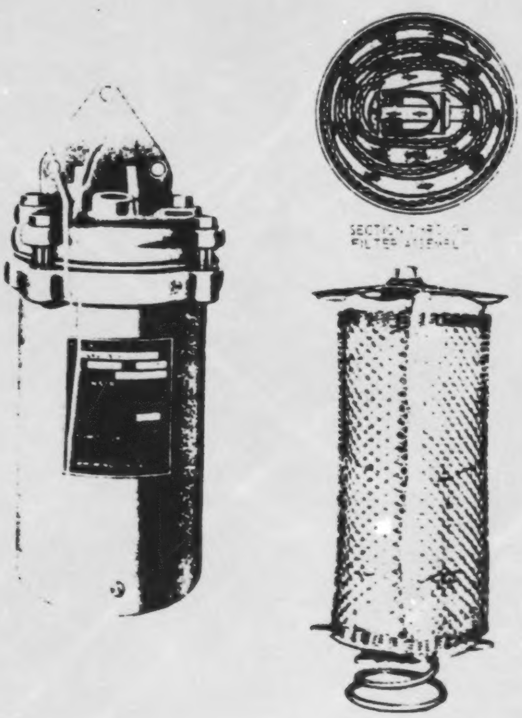

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Figure 8-7.—Cloth-type fuel filter.

order to mix the air and fuel more effectively. All modern combustion chambers may be classified under one of the following four designs: OPEN type, PRECOMBUSTION type, TURBULENCE chambers, DIVIDED chambers, and HYPERCYCLE combustion chambers. In construction equipment, the most common types are the open combustion chamber and the precombustion chamber.

OPEN COMBUSTION CHAMBER

The open combustion chamber (fig. 8-8) is the simplest form of chamber. The turbulence is generated as the piston comes up on the compression stroke by the design of the cylinder head and the piston crown. The injector is mounted in the cylinder head so that the end extends slightly below the bottom. The fuel is injected directly into the combustion space formed by the top of the piston and the cylinder head. The open chamber requires higher injection pressures and a greater degree of atomization to obtain the proper air-fuel mixture than the other types of combustion chambers. To equalize combustion in the combustion chamber, it uses multiple orfice-type injector tip for effective penetration and angle of spray.

PRECOMBUSTION CHAMBER

Figure 8-9 shows a diagram of a precombustion chamber. This chamber is usually separate from the cylinder head, but is screwed or pressed into the opening provided in the cylinder head. The precombustion chamber is water-cooled because it extends through the water jacket and into the bottom of the cylinder head. It must be sealed at both ends to prevent water leakage. As the piston moves up on the compression stroke, a small part of the compressed air enters the precombustion chamber where it swirls rapidly within a small space. The fuel nozzle is of the single hole type and is mounted into the precombustion chamber. As it is

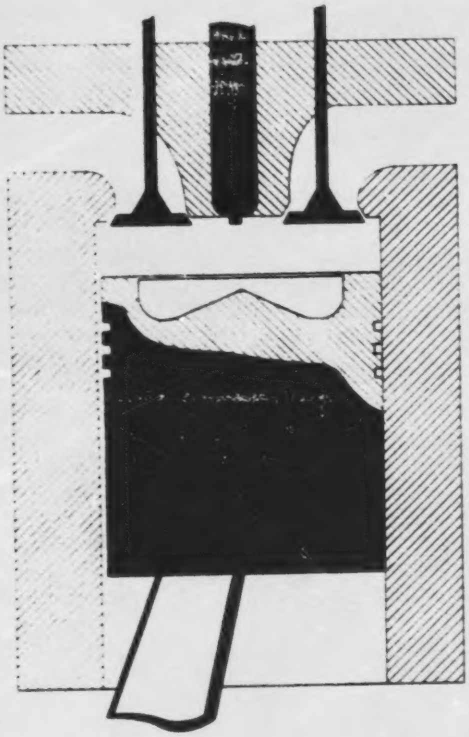

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Figure 8-8.—Diesel engine open combustion chamber.

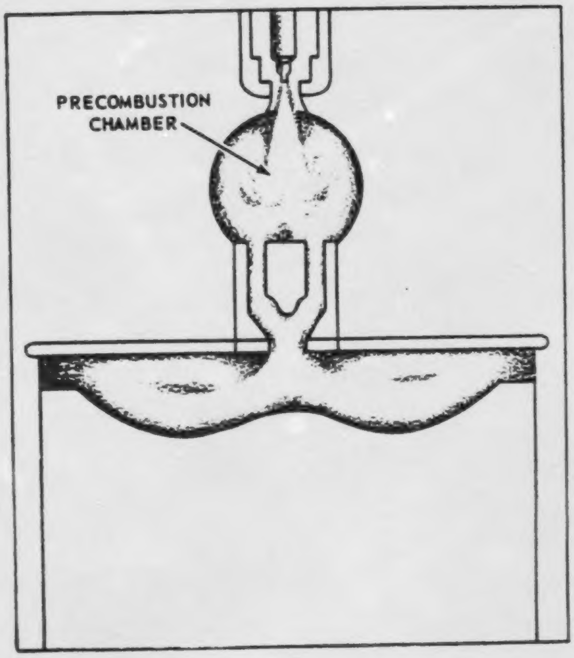

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Figure 8-9.—Diesel engine precombustion chamber.

injected from a single hole nozzle, the fuel is only slightly atomized and depends on this highly turbulent air for further atomization and ignition. Because of the high pressures generated inside the precombustion chamber by the small amount of air and fuel as it begins to burn, the remaining fuel is atomized and vaporized, as it is injected into the precombustion chamber and then forced into the main combustion space to complete the combustion process.

TURBULENCE CHAMBER

The turbulence chamber (fig. 8-10) is similar in appearance to the precombustion chamber, but its function is different. There is very little clearance between the top of the piston and the head, so that a high percentage of the air between the piston and the cylinder head is forced into the turbulence chamber during the compression stroke. The chamber is usually spherical, and the opening through which the air must pass becomes smaller as the piston reaches the top of the stroke. This increases the velocity of the air in the chamber. This turbulence speed is about 50 times crankshaft speed. The fuel injection is timed to occur when the turbulence in the chamber is greatest. This ensures a thorough mixing of the fuel and air, causing the greater part of combustion to take place in the turbulence chamber. The pressure created by the expansion of the burning gases is the force that drives the piston downward on the power stroke.

DIVIDED CHAMBER

The Lanova system is a combination of the precombustion chamber and the turbulence chamber. It is better known by the trade name Lanova combustion chamber.

In the Lanova system, the main volume of air remains in the main combustion chamber, and the principal combustion takes place therein. The system depends on a high degree of turbulence to bring about thorough mixing and distribution of fuel and air.

Basically, the Lanova system, not illustrated here, consists of a "figure eight" combustion chamber located centrally over the piston and a small air chamber called the ENERGY CELL, in which combustion takes place before combustion in the main chamber.

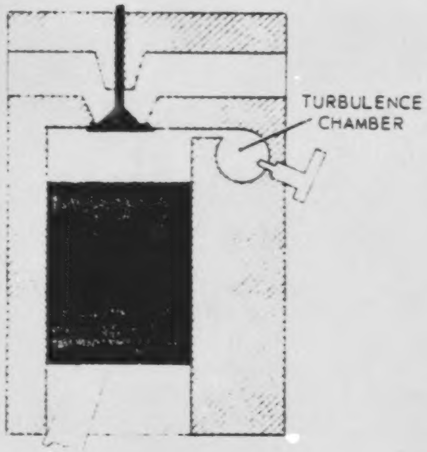

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Figure 8-10.—Diesel engine turbulence combustion chamber.

HYPERCYCLE CHAMBER

The hypercycle combustion chamber is relatively new to internal combustion engines. The action which takes place during each stroke in this type of combustion chamber is illustrated and explained in figure 8-11.

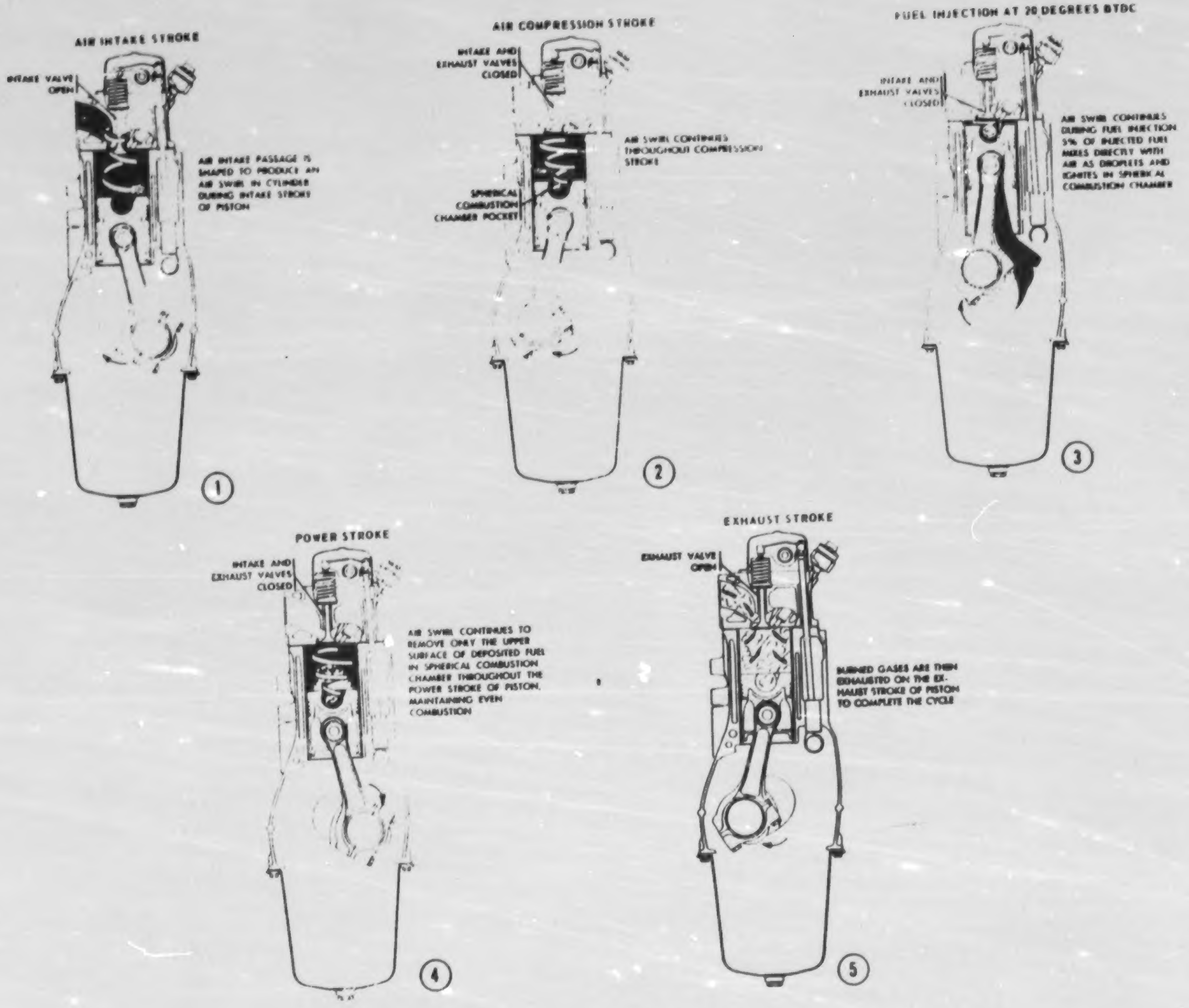
GOVERNORS

The speed and the power output of an engine are determined by the combustion process in the cylinders. Since combustion depends upon air and fuel, the speed and the output of an engine can be controlled by regulating the amounts of air and fuel supplied for the combustion process.

In diesel engines, a varying amount of fuel is mixed with a constant amount of compressed air inside the cylinder. A full charge of air enters the cylinder during each intake event. Since the quantity of air admitted is constant, combustion and, in turn, speed and power output are controlled by regulating the amount of fuel injected into the cylinders.

CONTROL OF ENGINE SPEED AND POWER

In a gasoline engine, speed and output are controlled by regulating the amount of air flowing into the cylinders of the engine. The


AIR INTAKE STROKE
INTAKE VALVE OPEN
AIR INTAKE PASSAGE IS SHAPED TO PRODUCE AN AIR SWIRL IN CYLINDER DURING INTAKE STROKE OF PISTON
①
AIR COMPRESSION STROKE
INTAKE AND EXHAUST VALVES CLOSED
AIR SWIRL CONTINUES THROUGHOUT COMPRESSION STROKE
SPHERICAL COMBUSTION CHAMBER POCKET
②
FUEL INJECTION AT 20 DEGREES BTDC
INTAKE AND EXHAUST VALVES CLOSED
AIR SWIRL CONTINUES DURING FUEL INJECTION 5% OF INJECTED FUEL MIXES DIRECTLY WITH AIR AS DROPLETS AND IGNITES IN SPHERICAL COMBUSTION CHAMBER
③
POWER STROKE
INTAKE AND EXHAUST VALVES CLOSED
AIR SWIRL CONTINUES TO REMOVE ONLY THE UPPER SURFACE OF DEPOSITED FUEL IN SPHERICAL COMBUSTION CHAMBER THROUGHOUT THE POWER STROKE OF PISTON, MAINTAINING EVEN COMBUSTION
④
EXHAUST STROKE
EXHAUST VALVE OPEN
BURNED GASES ARE THEN EXHAUSTED ON THE EXHAUST STROKE OF PISTON TO COMPLETE THE CYCLE
⑤

115.221

Figure 8-11.—Hypercycle combustion chamber.

carburetor is designed to control the air flow. The amount of air and its velocity, in turn, control the quantity of fuel with which the air is mixed before the mixture enters the cylinders.

The quantity and velocity of air flowing to the cylinders is controlled by the throttle valve. By operating the valve, you admit more or less air to the engine, and the carburetor automatically supplies the gasoline necessary to maintain the correct fuel-air ratio. Regulation of fuel or air supply by manual throttle control is adequate when engine speed and output requirements remain rather constant. However, the requirements of most engines used by the Navy vary because of fluctuating loads. The conditions under which construction equipment engines and the engine of a generating unit operate are examples of fluctuating loads. In road building, construction equipment constantly carry heavy loads outbound, but returns with no load. In the case of a generating unit, the demands for electricity are variable. Manual throttle control is not adequate to hold engine speed reasonably constant during such fluctuations in load. For this reason, a speed control device, or governor, is provided to prevent the engine from overspeeding and to allow the engine to meet changing load conditions.

RELATION OF GOVERNOR TO FUEL SYSTEM

Even though it is not a part of the fuel system, a governor is directly related to this system since it functions to regulate speed by control of the fuel or of the fuel-air mixture, depending upon the type of engine. In diesel engines, governors are connected in the linkage between the throttle and the fuel injectors. The governor acts, through the fuel injection equipment, to regulate the amount of fuel delivered to the cylinders. As a result, the governor holds engine speed reasonably constant during fluctuations in load. Since the speed and output of a gasoline engine depend on the amount of fuel-air mixture available, governors, when used on these engines, are so connected that they control the amount of the mixture flowing from the carburetor to the intake manifold.

Governors, like carburetors and fuel injection equipment, seem somewhat complicated unless one has a thorough understanding of the construction and operating principles of the equipment. As you progress through the Construction Mechanic rating, you will acquire, through practical experience and study, the knowledge necessary to understand the factors which may seem complicated at the present. For the time being, it is enough to understand the relationship of speed-control devices to the fuel system of an engine. For this reason, the information on governors which is given in this course is general in nature.

SPEED-REGULATING GOVERNORS FOR DIESEL ENGINE

The type of load and the degree of control desired determine the kind of governor to be used on a diesel engine. Since all governors used on diesel engines control engine speed through the regulation of the quantity of fuel delivered to the cylinders, these governors may be classified under the general heading of speed-regulating governors. Governors used on diesel engines may also be classified in various other ways, such as according to the function or functions performed, the forces utilized in operation, and the means by which the governor operates the fuel-control mechanism.

Governors are designed to control engine speed under varying load conditions. Since the type of load and the degree of control desired vary from one type of installation to another, the primary function of a governor depends upon the requirements of a particular installation.

Some installations require that engine speed remain constant from a no-load to a full-load condition. Governors which function to maintain a constant speed, regardless of load, are called CONSTANT-SPEED governors. Governors which maintain any desired engine speed between idle and maximum speeds are classified as VARIABLE-SPEED governors. Speed-control devices which are designed to keep an engine from exceeding a specified maximum speed and from dropping below a specified minimum speed are classified as SPEED-LIMITING governors. (In some cases, speed-limiting governors function only to limit maximum speed.) Some engine installations require a control device that limits the load which the engine will handle at various speeds. Such devices are called LOAD-LIMITING governors.

A governor may also be designed to perform two or more of the functions just listed. In this case, the operating mechanisms which perform the various functions are combined in a single unit.

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SPRING-LOADED CENTRIFUGAL GOVERNORS

In most of the governors installed on diesel engines used by the Navy, the centrifugal force of rotating weights (fly-balls) and the tension of a helical coil spring (or springs) are utilized in governor operation. On this basis, most of the governors used on diesel engines are generally called SPRING-LOADED CENTRIFUGAL governors.

In spring-loaded centrifugal governors, two forces oppose each other. One of these forces is the tension of a spring (or springs) which may be varied either by an adjusting device or by movement of the manual throttle. The other force is produced by the engine. Weights attached to the governor drive shaft are rotated, and a centrifugal force is created when the shaft is driven by the engine. The centrifugal force varies directly with the speed of the engine.

Transmitted to the fuel system through a connecting linkage, the tension of the spring (or springs) tends to increase the amount of fuel delivered to the cylinders. On the other hand, the centrifugal force of the rotating weights, through connecting linkage, tends to reduce the quantity of fuel injected. When the two opposing forces are equal, or balanced, the speed of the engine remains constant.

To illustrate how the centrifugal governor works, let us assume that an engine operates under load, and that the opposing forces in the governor are balanced, so that the engine speed is constant. If the load is increased, the engine speed decreases, resulting in a reduction in the centrifugal force of the fly-balls. The spring tension then becomes the greater force and it acts on the fuel-control mechanism to increase the quantity of fuel delivered to the engine. The increase in fuel results in an increase in engine speed until balance of the forces is again reached.

When the load on an engine is reduced or removed, the engine speed increases and the centrifugal force within the governor increases. The centrifugal force then becomes greater than the spring tension and acts on the fuel control linkage to reduce the amount of fuel delivered to the cylinders. This causes the engine speed to decrease until a balance between the opposing forces is again reached and engine speed becomes constant.

OTHER CLASSIFICATIONS OF GOVERNORS

Governors are also classified according to the method by which fuel-control mechanisms are regulated. In some cases, the centrifugal force of the rotating weights regulates the fuel supply directly, through a mechanical linkage which operates the fuel-control mechanism. Other governors are designed so that the centrifugal force of the rotating weights regulates the fuel supply indirectly, by moving a hydraulic pilot valve which controls oil pressure. Oil pressure is then exerted on either side of a power piston which operates the fuel-control mechanism.

Governors which regulate the fuel supply directly (through mechanical linkage) are called MECHANICAL GOVERNORS; and those which control the fuel supply indirectly (through oil pressure) are called HYDRAULIC GOVERNORS. Simple governors of the mechanical and hydraulic types are shown in figures 8-12 and 8-13, respectively.

Note that in the illustration of the mechanical governor the weights, or flyballs, are in an upright position. This indicates that the centrifugal force of the weights and the tension of the spring are balanced; in other words, the engine is operating at constant load and speed. In the case of the hydraulic governor, the positions of the parts indicate that the engine is responding to an increase in load with a resulting decrease in engine speed. Note that the weights tilt inward at the top. As engine speed decreases, the spring tension overcomes the centrifugal force of these rotating weights. When the spring tension is greater than the centrifugal force of the flyballs, the governor mechanism acts to permit oil under pressure to force the piston to increase the fuel valve opening. The increased fuel supply causes an increase in engine power output and speed. The governor regulates the fuel supply so that enough power is developed to handle the increase in load.

Hydraulic governors are more sensitive than those of the mechanical type. Also, the design of a hydraulic governor enables a comparatively small governing unit to control the fuel mechanism of a large engine. The mechanical governor is used more often on small engines, which do not require extremely close regulation of the fuel. Hydraulic governors

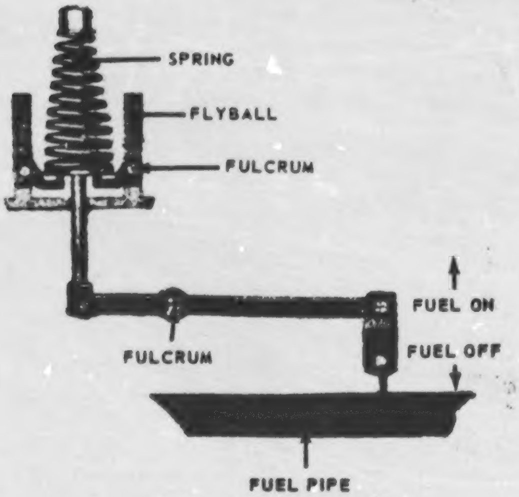

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Figure 8-12.–Simple mechanical governor.

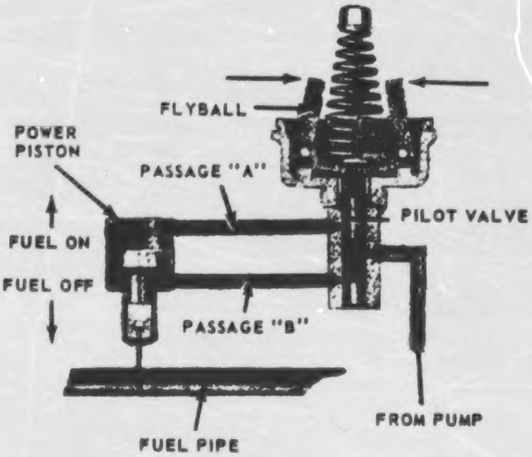

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Figure 8-13.–Simple hydraulic governor.

are more suitable to large engines, in which more accurate regulation of fuel is necessary.

DANGER OF EXCESSIVE SPEED

Engines which are maintained in proper operating condition seldom reach speeds above those for which they are designed. However, there may be times when speeds become too high. The operation of an engine at excessive speeds is extremely dangerous. If the engine speed is high enough, the high inertia and centrifugal force developed may cause parts to become seriously damaged or even to fly apart. Therefore, it is essential that you know why an engine may reach a dangerously high speed, and how it may be brought under control when too much speed occurs.

CAUSES OF EXCESSIVE SPEED

In some 2-stroke cycle engines, lubricating oil may leak into the cylinders as a result of leaky blower seals or broken piping. Even though the fuel is shut off, the engine may continue to operate, or even run away, as a result of this combustible material coming from the uncontrolled source. Engines in which lubricating oil may accumulate in the cylinders are generally equipped with an automatically operated mechanism which shuts off the intake air at the inlet passage to the blower. If no air shut-off mechanism is provided and shutting off the fuel will not stop an engine which is overspeeding, anything which can be placed over the engine's air intake to stop air flow, such as a piece of canvas or even a pair of dungarees, will stop the engine.

Excessive engine speeds more commonly result from an improperly functioning regulating governor than from any other cause. The usual method of accomplishing an emergency shut down when the regulating governor fails to function properly is to shut off the fuel oil supply to the cylinders. If this fails to slow the engine or stop it, the air supply to the engine must be cut off.

CAUTION: Do no risk personal injury to stop an overspeeding engine when all normal means have failed.

STOPPING FUEL SUPPLY

Shutting off the fuel supply to the cylinders of an engine may be done in various ways. The fuel-control mechanism may be forced to the NO FUEL position; the fuel line may be blocked by closing a valve; the pressure in the fuel injection line may be relieved by opening a valve;

or the mechanical movement of the injection pump may be prevented. These methods of shutting off the fuel supply may be done either manually or automatically.

OVERSPEED SAFETY DEVICES

Automatic operation of fuel and air control mechanisms is accomplished by overspeed safety devices. As emergency controls, these safety devices operate only in the event the regular speed governor fails to maintain engine speed within the maximum design limit. Devices which function to bring an overspeeding engine to a full stop by completely shutting off the fuel or air supply are generally called OVERSPEED TRIPS. Devices which function to reduce the excessive speed of an engine, but allow the engine to operate at safe speeds, are called OVERSPEED GOVERNORS.

All overspeed governors and trips depend upon a spring-loaded centrifugal governor element for their operation. In overspeed devices, the spring tension is great enough to overbalance the centrifugal force of the weights until the engine speed rises above the desired maximum. When an excessive speed is reached, the centrifugal force overcomes the spring tension and operates the mechanism which stops or limits the fuel or air supply.

GOVERNORS AS SAFETY DEVICES

When a governor serves as the safety device, the actual operation of the fuel or air control mechanism by centrifugal force may be brought about directly, as in a mechanical governor, or indirectly, as in a hydraulic governor. In the case of an overspeed trip, the shutoff control is operated by a power spring. The spring is placed under tension when the trip is manually set, and held in place by a latch. If the maximum speed limit is exceeded, a spring-loaded centrifugal weight moves out and trips the latch, allowing the power spring to operate the shutoff mechanism.

ELECTRICAL SYSTEM

Since the electrical systems used on diesel engines are similar to those used on gasoline engines, the information given in chapters 6 and 7 will generally apply to electrical systems on diesel engines.

The manufacturer's manual will explain any unusual features in the electrical system of any engine with which you may be working.

LUBRICATION SYSTEM

One of the most important items contributing to the long life of an engine is that of proper lubrication. The main job of the lubrication system is to overcome friction between moving parts. If this friction is not eliminated, moving parts will melt, fuse, or seize after a very short period of engine operation.

An adequate lubricating system has been provided to meet a wide variety of working conditions of our modern diesel and gasoline internal combustion engines. It is up to you the MECHANIC to keep this system functioning properly.

The major difference between the lubrication systems of the gasoline and the diesel engine, is that the latter normally contains an oil cooler (fig. 8-14). The oil pump draws the oil from the oil pan, through the strainer, and goes to the oil cooler. After leaving the oil cooler (where the water from the cooling system removes the heat from the oil), the oil enters the main gallery (constantly under pressure) in the cylinder block; from here it is distributed through small holes and openings to the various moving parts and bearings.

COOLING SYSTEM

There are two types of cooling systems employed in diesel engines. One type uses the principle of the heat exchanger. The heat exchanger is a device that transfers heat from one fluid or liquid to another. (The oil cooler mentioned earlier is an example of a heat exchanger.)

The most common type of diesel cooling system is a radiator and cooling fan. Heat is removed by circulating water through water jackets surrounding the hottest parts of the engine (cylinders and the full length of piston travel). Heat is transferred to the water while the water is being pumped through the passages of the cylinder block and up into the cylinder head. The water then passes through the upper hose connection and the heated water is carried into the radiator. As the water flows down through the radiator the heat is removed by a stream of air forced through the radiator by the action of the fan. From the bottom of the

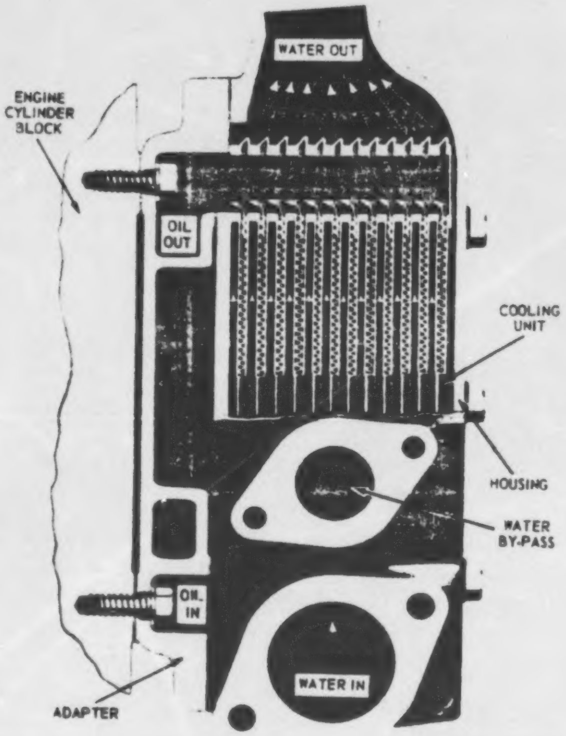

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Figure 8-14.—Sectional view of an oil cooler.

radiator, the water flows through the lower hose connection to the pump, where it is again forced into the water jackets to repeat the cooling cycle (See fig. 8-15.)

DIESEL ENGINE STARTING SYSTEMS

Starting diesel engines is more difficult than starting gasoline engines because of the high compression required within the cylinders. At low temperatures, starting becomes the most difficult problem associated with diesel equipment operation. The difficulty lies in generating, by compression, adequate heat in the combustion chamber to ignite the fuel injected into the engine cylinder. The maximum temperature generated within the cylinder depends partly on the initial temperature of the fuel and air as they are introduced into the cylinder. In addition, the temperature depends on the cranking speed of the engine. To enable a satisfactory engine start, the engine must be cranked at a relatively high speed.

There are several cranking systems in use on diesel engines. These systems include:

1. The conventional electrical system consisting of a storage battery and cranking motor.
2. An auxiliary power unit consisting of a small gasoline engine which cranks the diesel engine.
3. A pneumatic unit consisting of a compressed air reservoir, and an air-driven cranking motor.
4. A hydraulic combination consisting of an oil pump, a high pressure accumulator, and a hydraulic oil-driven motor.

More information relating to the starting systems on specific engines is included in chapter 9 of this course.

SERVICE AND MAINTENANCE

There is probably no other equipment in the Navy that operates under worse conditions than your earth moving equipment. The dirt and dust kicked up by the dozing, grading, and digging operations are the worst enemy of the internal combustion engine. Therefore, you must constantly keep check on your oil filters, air cleaner, water, oil, and fuel systems.

Daily inspections should include visual inspections for leaks in all engine systems—oil, water, fuel, and air. Replace lines and fittings that show evidence of wear or leaks and tighten all connections. Use the proper tools to tighten fittings. Remember, stripped threads and rounded corners on pipe connections are evidence of improper maintenance.

DETECTING FAULTY ENGINE OPERATION

A misfiring cylinder can be detected by checking the exhaust fittings leading from the individual cylinders. The coolest cylinder is usually the offender.

An unusually hot exhaust pipe indicates a cylinder receiving an improper mixture-usually too much fuel or late fuel injection. Fuel not completely burned inside the cylinder continues to burn in the exhaust manifold, and results in excessive heat. The exhaust gases, mixed with unburned fuel particles, leave the manifold in

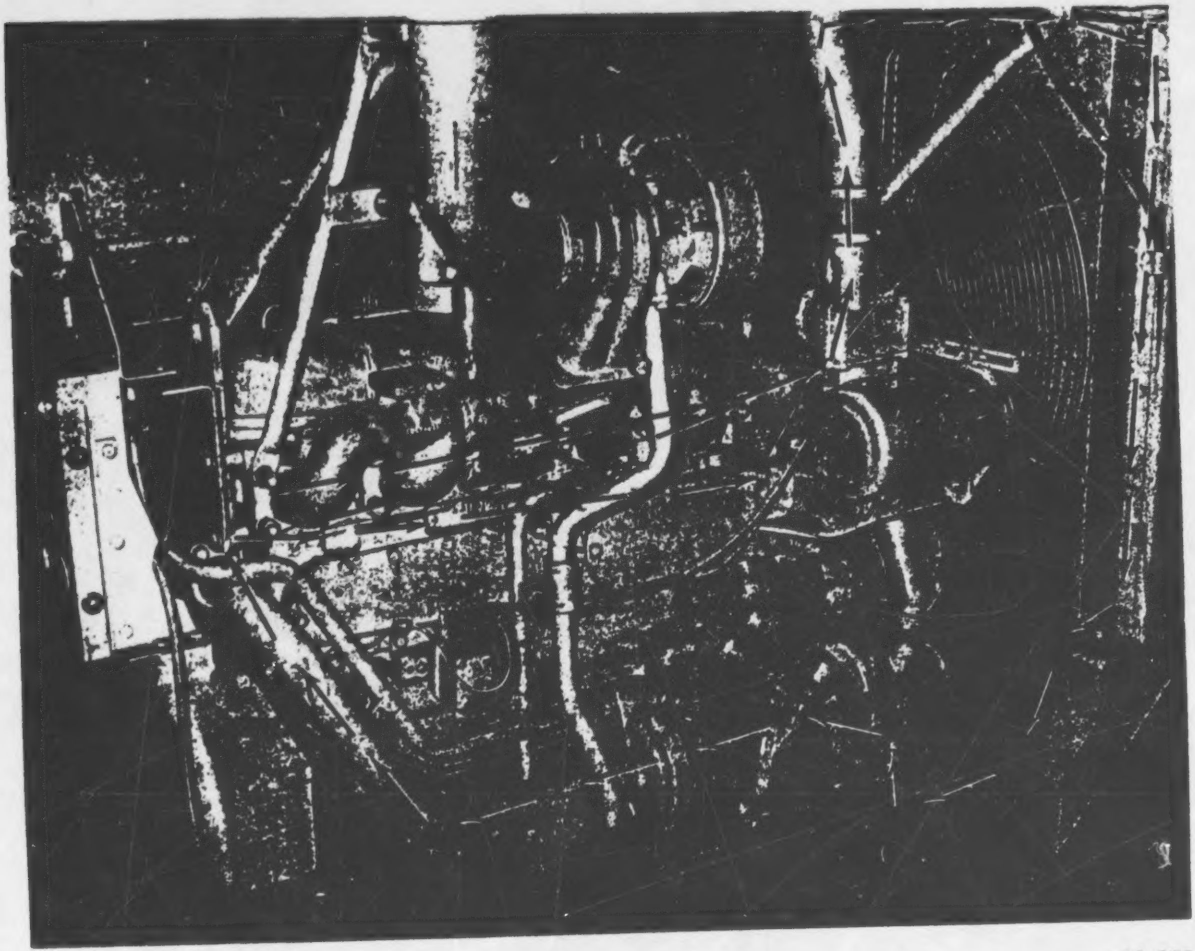

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Figure 8-15.—Cooling system for International engine.

the form of brown or black smoke. The smoky exhaust gases may also indicate the use of improper fuel and worn piston rings.

Engine or fuel KNOCKS can result from fuel injection timed too early, spray-nozzle valves failing to close properly, and dirt or water in the fuel. It is obvious then, that most diesel-engine operating troubles can be traced to improper fuel injection, and dirt or other foreign matter in the system.

NOZZLE CLEANING, TESTING, AND ADJUSTMENT

The first step before working on fuel injection equipment is to get a clean space on a bench. Have all the equipment ready with plenty of clean, soft tissues (toilet tissues) or lint-free cloths. Handle all parts carefully and follow the directions in the manufacturer's instruction manual. In particular, never use hard or sharp tools, emery cloth, grinding compounds, or any abrasives on injection-nozzle parts.

If an injector appears to be faulty, you can perhaps learn why it is faulty by using a nozzle tester. This instrument may be used without taking the injector apart. Nozzle testers, all work on the same principle. The injector is connected to a hand pump with which you force oil through the injector. A pressure gage is attached to the pump so that you can read directly

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the opening pressure at which the injector is set. You can easily test for leakage, and see the spray pattern as the oil comes out of the injector.

ADJUSTING VALVE OPERATING MECHANISMS

Intake and exhaust valves are operated by rocker arms and push-rod assemblies working off the engine camshaft. It is important that the proper clearance (valve lash) be maintained in the linkage to compensate for expansion as the engine heats up.

Too much clearance will cause noise, and the valves will not remain open long enough.

Too little clearance will prevent proper seating and will cause burnt and leaky valves.

The adjustment of valve clearances can generally be changed by an adjustment screw in the rocker arm or by a threaded part of the push rod. (See fig. 8-16.) A locknut is provided with either device.

The manufacturer's manual will give the proper setting and the valve adjustment procedures.

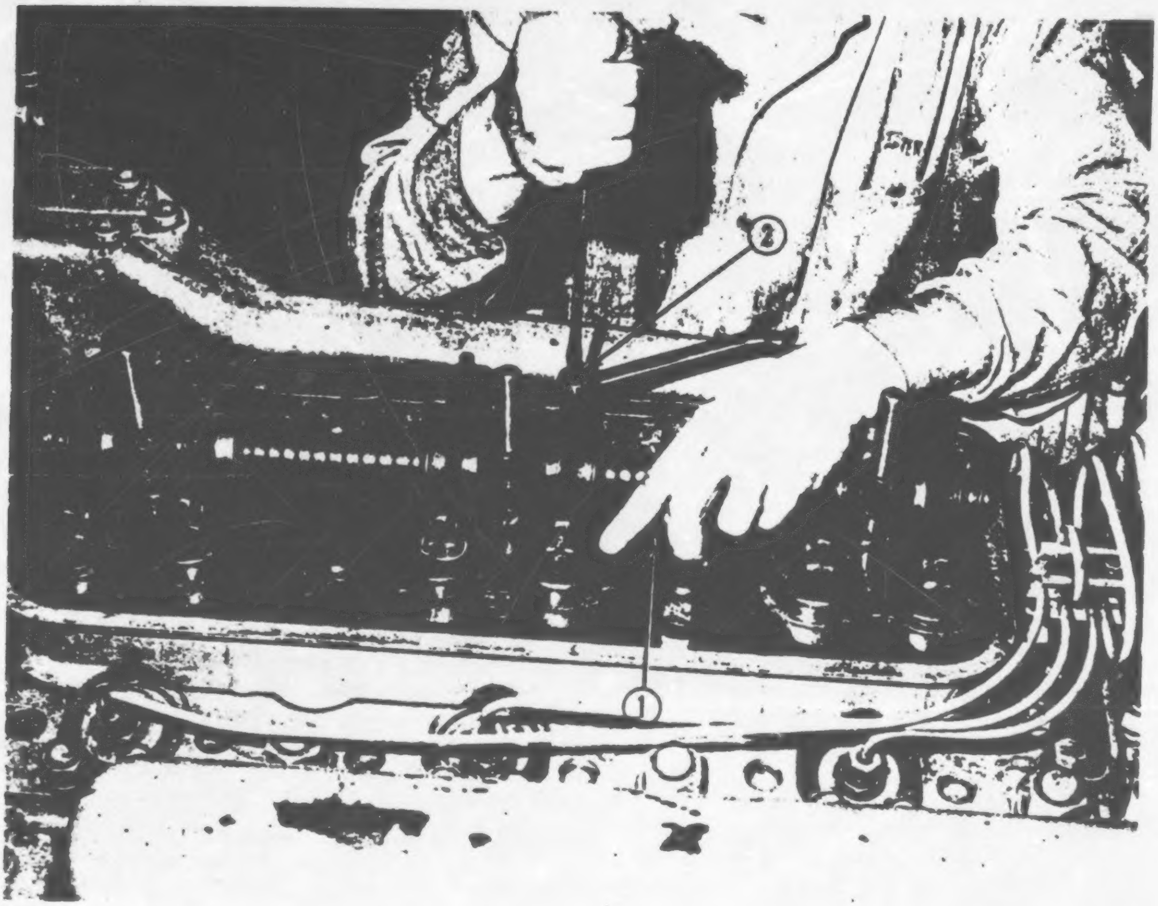

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Figure 8-16.–Adjusting valve clearance in Caterpillar diesel engine.

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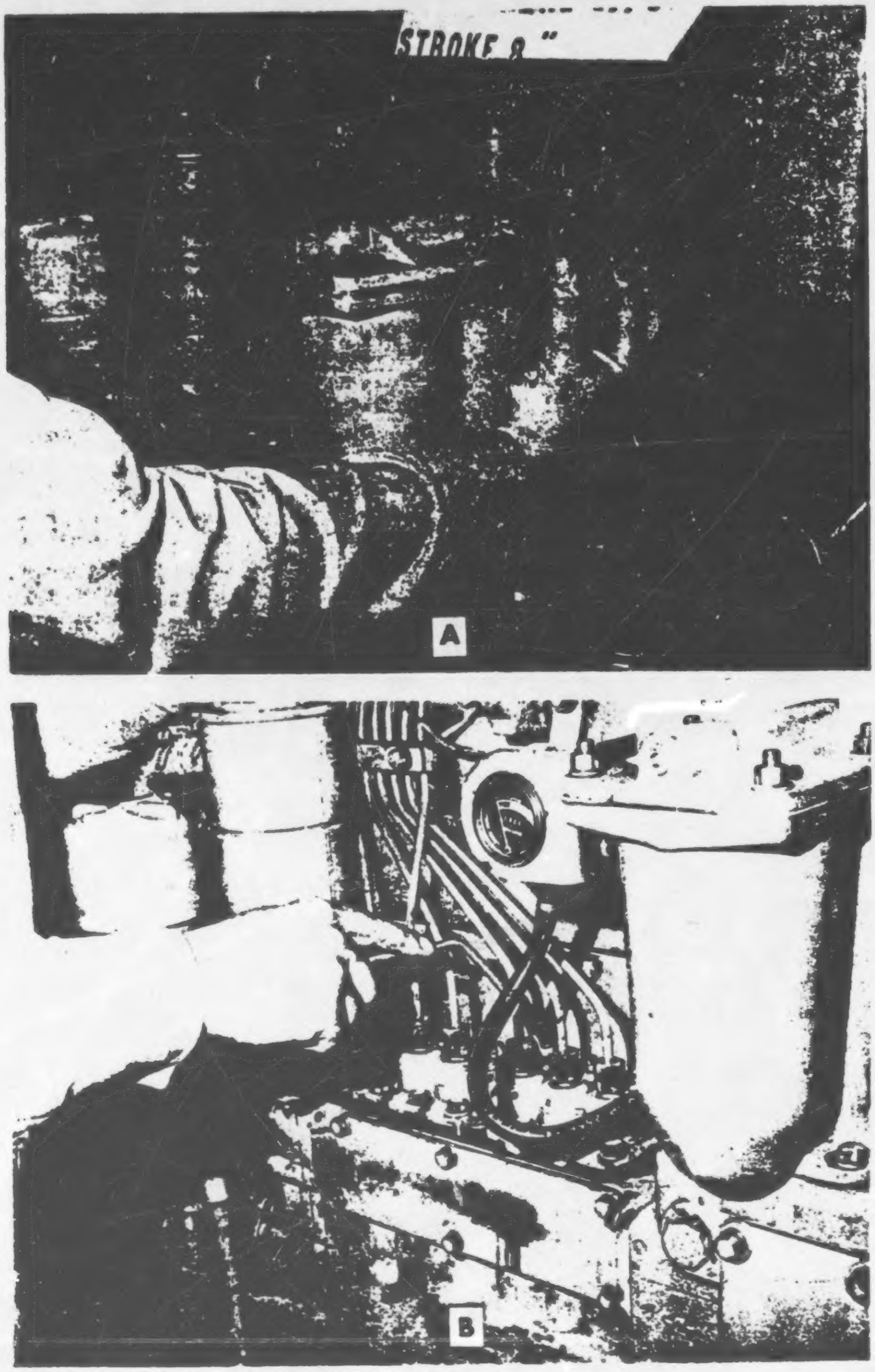

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Figure 8-17.—Bleeding the fuel system.

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CHECKING THE AIR INTAKE SYSTEM

To check the blowers or superchargers for oil leaks, remove the blower inspection plate or the inlet connection so that you can check the ends of the lobes or rotors and case for oil leaks around the seals. If wet oil appears at the ends of the rotors or if there is excessive oil consumption, the seals should be replaced. In making your inspection be sure you check all oil lines and connections for leaks, and correct as required.

In checking the turbocharger, you should check both the intake and exhaust sides for wet oil leaks; if oil is present check to see that it is not caused by worn rings or oil-over-condition from the air cleaner. Like the blower and supercharger, check all oil lines and connections for leaks, and correct as required.

PRIMING THE FUEL SYSTEM

Any time the fuel flow is broken and air enters the fuel system, the fuel system must be primed. This process is often called bleeding the system. If air is left in the lines, the fuel system may be airbound, resulting in inability to start the diesel engine or missing of one or more cylinders.

If the engine will not start, open the main fuel line vent. Then crank the engine until a flow of fuel through the vent becomes continuous and contains no air bubbles. Be sure the vent is closed before attempting to restart the engine. Figure 8-17 shows the location of the vents in the Caterpillar diesel. If one or more cylinders are MISSING when the engine is running, it may be necessary to open the individual vents, view A, or fuel lines, view B, leading from the injection pumps to the cylinders to remove remaining air bubbles. For complete details on the priming procedure, consult the manufacturer's manual.

In servicing the diesel engine, bear in mind that it has essentially the same engine systems you will find on the gasoline engine. With the exception of the fuel systems, maintenance of both engines is the same. Make your inspections according to the shop preventive maintenance schedule. A good mechanic keeps abreast of the changes in his equipment.

DIESEL ENGINE (MULTIFUEL)

In some of the present types of military vehicles, such as the 2 1/2 ton cargo truck, M35A1, a multifuel diesel engine is being utilized. This engine is basically the same as other conventional type diesel engines in respect to internal moving parts. The unique feature of this engine (as the name multifuel implies) is that it is capable of operating on more than one type of fuel. The engine operates on the 4-stroke cycle principle and is a compression ignition engine.

The M35A1, LD 465-1, and LDS465-1 multifuel engines can operate successfully on diesel fuel, and regular grade gasoline. High octane fuels, such as aviation or premium gasolines, should not be used. No modifications or adjustments are necessary when changing types of fuel. A fuel density compensator is provided as a part of the fuel injector pump thereby automatically maintaining maximum engine power, for that fuel, regardless of the type of fuel, or mixture of fuels being used in the engine.

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CHAPTER 9

SOME COMMON MODELS OF DIESEL ENGINES

The previous chapter treated the diesel engine generally as a mechanical unit. In this chapter, we will consider operative principles of some specific models. These are some of the common models used by the Seabees to power tractors and other heavy duty and construction equipment.

This chapter will also include some information on diesel engine maintenance in both a general and specific manner.

GENERAL MAINTENANCE

Modern diesel engines are products of much research, skillful engineering, and precision manufacturing. When given proper care and maintenance they will give many hours of satisfactory service.

Because a diesel engine depends on the heat of compression for ignition and proper combustion, it is necessary, for efficient operation, that the engine run in the heat range specified by the manufacturer. If an engine is running too hot or too cold, check the cooling system, including the water pump and fan belt. It may be necessary to remove and test the thermostats. Pressure type cooling systems are provided on most modern equipment. This enables an engine to operate at a higher temperature without boiling the coolant. The pressure relief valve in the system (usually in the radiator cap) should be checked periodically. If the pressure becomes too great, there is danger of blowing a radiator hose or rupturing a tube in the radiator core.

The electrical charging and starting circuits of diesel engines are much the same as in gasoline engines. These have been discussed in chapters 6 and 7 of this book.

Fuel systems of diesel engines will be discussed in this chapter. If all diesel engines had nearly identical fuel systems (like gasoline engines) trouble diagnosis and maintenance procedures could follow a general pattern much like the one that is used for gasoline engines. But, with the exception of similar fuel tanks, filters, and a basic piping system, diesel engine fuel systems differ considerably. Consequently, each engine manufacturer recommends different specific maintenance procedures. Those described herein for the more popular International, Caterpillar, Cummins, and General Motors diesels are by no means all you will need to know. However, the tune-up and maintenance procedures described are representative of jobs you will do. For all jobs you do not thoroughly understand, refer to the manufacturers' maintenance manuals.

DIRT IN FUEL SYSTEM

Many diesel engine operating troubles result directly or indirectly from dirt in the fuel system. That is why proper fuel storage and handling is so important. One of the most important aspects of diesel fuel is cleanliness. The fuel should not contain more than a trace of foreign substance; otherwise, fuel pump and injector troubles will occur. Diesel fuel, because it is more viscous than gasoline, will hold dirt in suspension for longer periods. Therefore every precaution should be made to keep the fuel clean.

If the engine starts missing, running irregularly, rapping, or puffing black smoke from the exhaust manifold, look for trouble at the spray nozzle valves. In this event, it is almost a sure bet that dirt is responsible for improper fuel injection into the cylinder. A valve held open or scratched by particles of dirt so that it cannot seat properly will allow fuel to pass into the exhaust without being completely burned, causing black smoke. Too much fuel may cause a cylinder to miss entirely. If dirt prevents

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the proper amount of fuel from entering the cylinders by restricting spray nozzle holes, the engine may skip, or stop entirely. In most cases, injector or spray valve troubles are easily identified.

Improper injection pump operation, however, is not so easily recognized. It is more likely caused by excessive wear than by an accumulation of dirt or carbon such as the spray nozzle is subjected to in the cylinder combustion chamber. If considerable abrasive dirt gets by the filters to increase (by wear) the very small clearance between the injector pump plunger and barrel, fuel will leak by the plunger instead of being forced into the injector nozzle in the cylinder. This gradual decrease in fuel delivery at the spray nozzle may remain unnoticed for some time, or until the Equipment Operator complains of sluggish engine performance.

Although worn injector pumps will result in loss of engine power and hard starting, worn piston rings, cylinder liners, and valves (air intake or exhaust) can be responsible for the same conditions. However, with worn cylinder parts or valves, the hard starting and loss of power will be accompanied by poor compression, a smoky exhaust, and excessive blow-by from the crankcase breather.

WATER IN FUEL SYSTEMS

It requires only a little WATER in a fuel system to cause an engine to miss, and if present in large enough quantities, the engine will stop entirely. Many fuel filters are designed to clog completely when exposed to water, thereby stopping all fuel flow. Water that enters a tank with the fuel oil, or that forms by condensation in a partially empty tank or line, usually settles to the lowest part of the fuel system. This water should be drained off daily.

AIR IN FUEL SYSTEMS

Air trapped in diesel fuel systems is one of the main reasons for a hard starting engine. Air can enter the fuel system at loose joints in the piping or through a spray nozzle that does not close properly. Letting the vehicle run out of fuel will also cause air to enter the system. Like water, air can interfere with the unbroken flow of fuel from the tank to the cylinder. A great deal of air in a system will prevent fuel pumps from picking up fuel and pushing it through the piping systems. Air can be removed by bleeding the system as set forth in the procedures described in the manufacturer's maintenance manual.

SERVICING INJECTION EQUIPMENT

Diesel injection parts (injectors or spray valves and pumps) are assembled units of precision parts; they cannot be cleaned or adjusted adequately in the field. To operate efficiently, they must be cleaned, repaired, and adjusted with special equipment.

Proper arrangement and suitable housing of injector test apparatus are essential so that the apparatus can be given proper care and protection.

CLEANING INJECTORS

Unless special servicing equipment and repair instructions are available, defective nozzles and pumps are usually exchanged for new ones. However, in an emergency, and if spray valves or pumps are not too badly worn, they may be returned to a serviceable condition, with minor adjustment, after a thorough cleaning.

Injector spray nozzles or pumps should never be disassembled in the field. They should be removed from the equipment and brought to the shop for repair. The first requirement for the cleaning job is a clean working space.

Use clean diesel fuel for washing the parts. Disassemble one nozzle or pump assembly at a time to prevent mixing of mating parts. Exercise care to prevent damage to nozzle and pump parts. Inspect and clean all parts as they are disassembled. Carbon may be scraped from the outside of the nozzle, but be careful not to mar the edges of the holed (orifices). When cleaning fluid is used to clean pump and nozzle parts, dip the parts in diesel fuel immediately after cleaning. This will prevent moisture from the hands from marring the highly polished surfaces.

Reaming tools and special drills are provided for cleaning spray nozzle holes. No drills other than those recommended by the manufacturer should be used. The drills are hand operated, the smaller, needle-type, being held with a small chuck called a "pin vise" (fig. 9-1).

In performing reaming operations, remove only the foreign matter; be particularly careful not to burr the metal.

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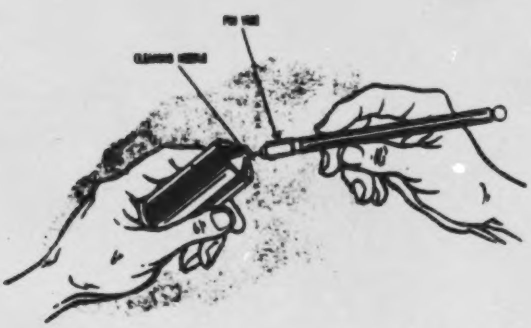

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Figure 9-1.—Cleaning injector spray nozzle holes.

TESTING FUEL INJECTION

When fuel injection troubles are suspected, and before removing the injector nozzles for shop testing, it is a good practice to check the injectors to find out if just one of them is causing the trouble. To do so, first operate the engine at a speed at which the defect is more pronounced. While the engine with the pump and nozzle fuel system operates at this speed, loosen the fuel line connection at each injection pump one at a time to "cut out" the cylinder. When you find one that makes very little or no difference in the irregular operation of the engine, the injector for that cylinder is probably causing the trouble and needs to be removed and tested. It is seldom that one injector valve alone is responsible for all the trouble. Therefore, you should continue the testing until all injectors have been tested.

More will be said about injector testing later in this chapter when troubleshooting and maintenance of fuel systems of specific models of engines are discussed.

Up to now what has been said applies generally to all fuel systems.

CATERPILLAR DIESEL ENGINE

The Caterpillar diesel is a 4-stroke cycle engine manufactured in 4-, 6-, 8-, and 12-cylinder models. It is made with in-line or with V-blocks, to drive road machinery, shovels, and stationary industrial and marine equipment, as well as tractors. Figures 9-2 and 9-3 show cross sections of a Caterpillar diesel engine. The designations D-7, D-8, D-9 and so on indicate the size of the tractor.

The Caterpillar is started by a 4-stroke cycle, 2-cylinder gasoline engine (fig. 9-4), or by direct starting with an electric starting motor.

From figure 9-4 you can get an idea of the relative size of the starting engine. The assembly includes a magneto ignition and one of two types of clutch. The engine with a WET-TYPE, multiple-disk clutch and the engine with a DOUBLE-PLATE, SPRING-TYPE clutch both have a two speed transmission. The transmission has a HIGH RANGE for normal starting and LOW RANGE for cold weather starting. Figure 9-5 shows a clutch and transmission assembly of a gasoline starting engine.

Many of the late model Caterpillar diesel engines are direct-start diesel engines and do not use the gasoline starting engines. They use a 24-volt starting motor, which is geared directly to the diesel engine flywheel, and a series parallel starting switch. The starting motor and the series parallel switch are explained in chapter 7 of this manual.

In cold weather, the gasoline starting engine is advantageous in that it will crank the diesel engine for a prolonged period of time, circulating the lubricating oil and coolant in the diesel engine before it is started. The exhaust pipe of the starting engine runs through the intake manifold of the diesel engine, thus the intake air of the diesel is warmed prior to entering the cylinders.

The Caterpillar diesel has a compression release mechanism that holds valves off their seats. In some models of engines the intake valves are held open, while in others the exhaust valves are open. When the compression release lever is engaged, the engine is easy to crank.

The procedure for starting a Caterpillar diesel differs with the model of the engine. Therefore, no exact starting procedure will be given in this manual. If in doubt about the

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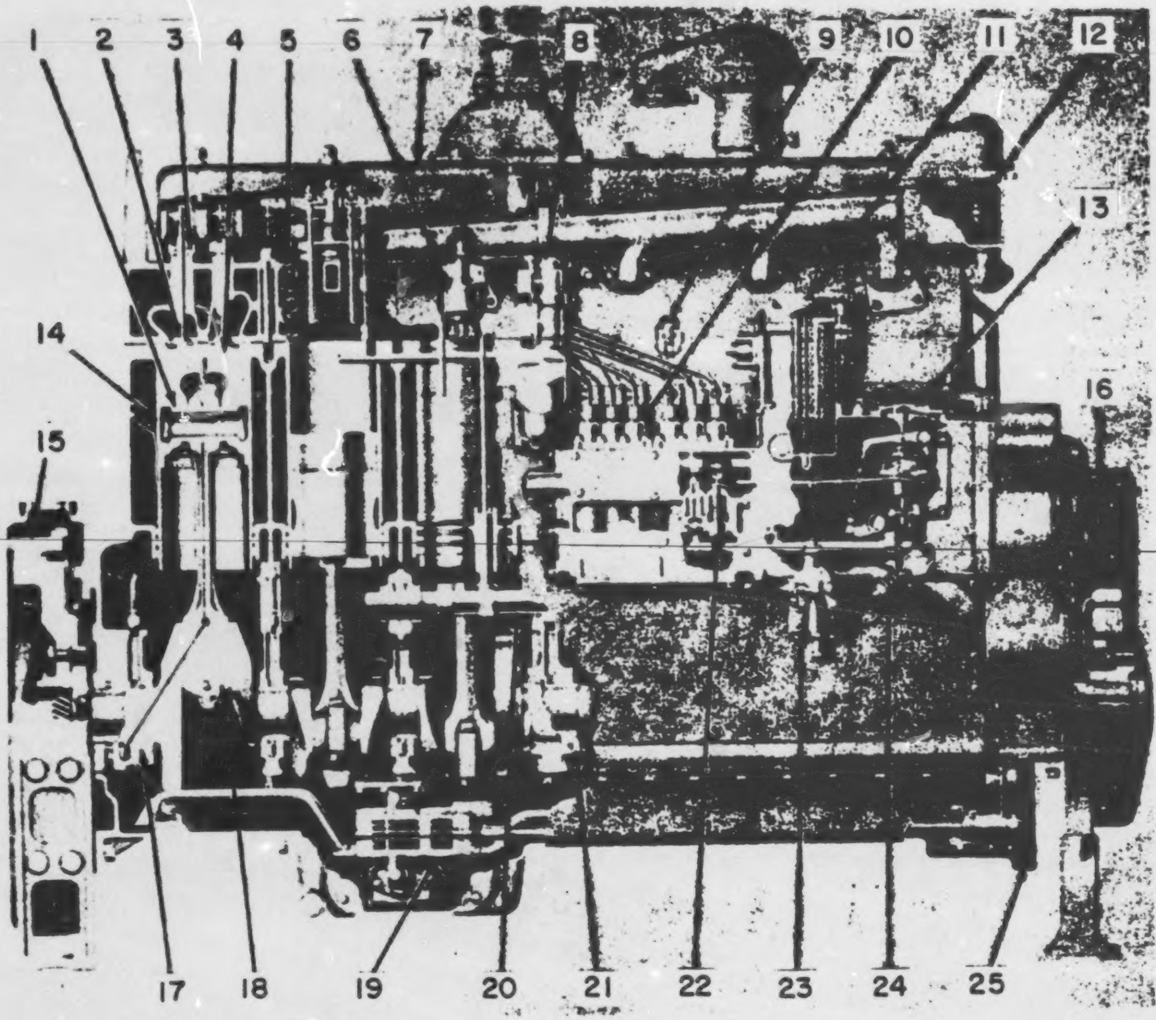

1. Piston pin.
2. Valve.
3. Valve rotator.
4. Piston.
5. Head.
6. Precombustion chamber.
7. Valve cover.
8. Crankcase breather.
9. Water director.
10. Fuel injection pump.
11. Fuel filter.
12. Water temperature regulator.
13. Governor.
14. Cylinder liner.
15. Flywheel.
16. Vibration damper.
17. Rear main bearing.
18. Connecting rod bearing.
19. Oil pump.
20. Camshaft.
21. Center main thrust bearing.
22. Fuel pump lifter assembly.
23. Fuel transfer pump.
24. Hour meter.
25. Oil pump drive gear.

81.340

Figure 9-2.—6-cylinder Caterpillar diesel engine-right side (cutaway view).

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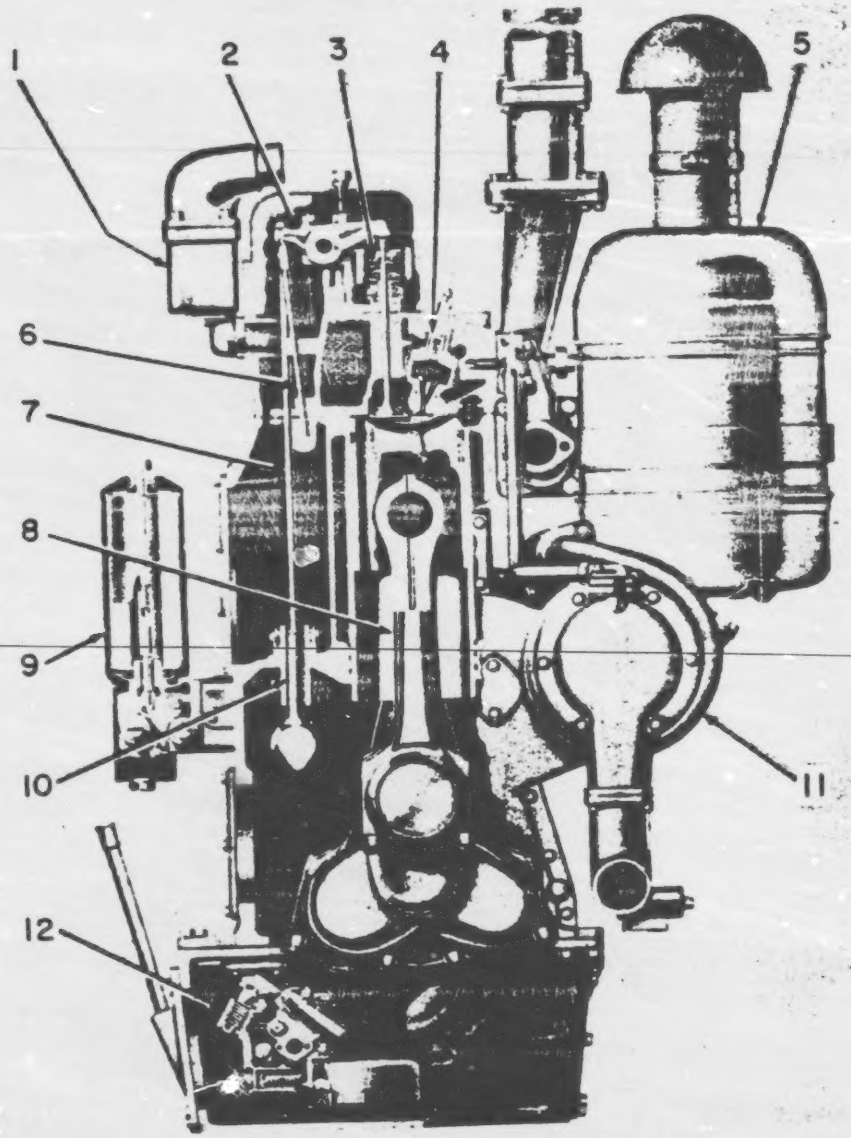
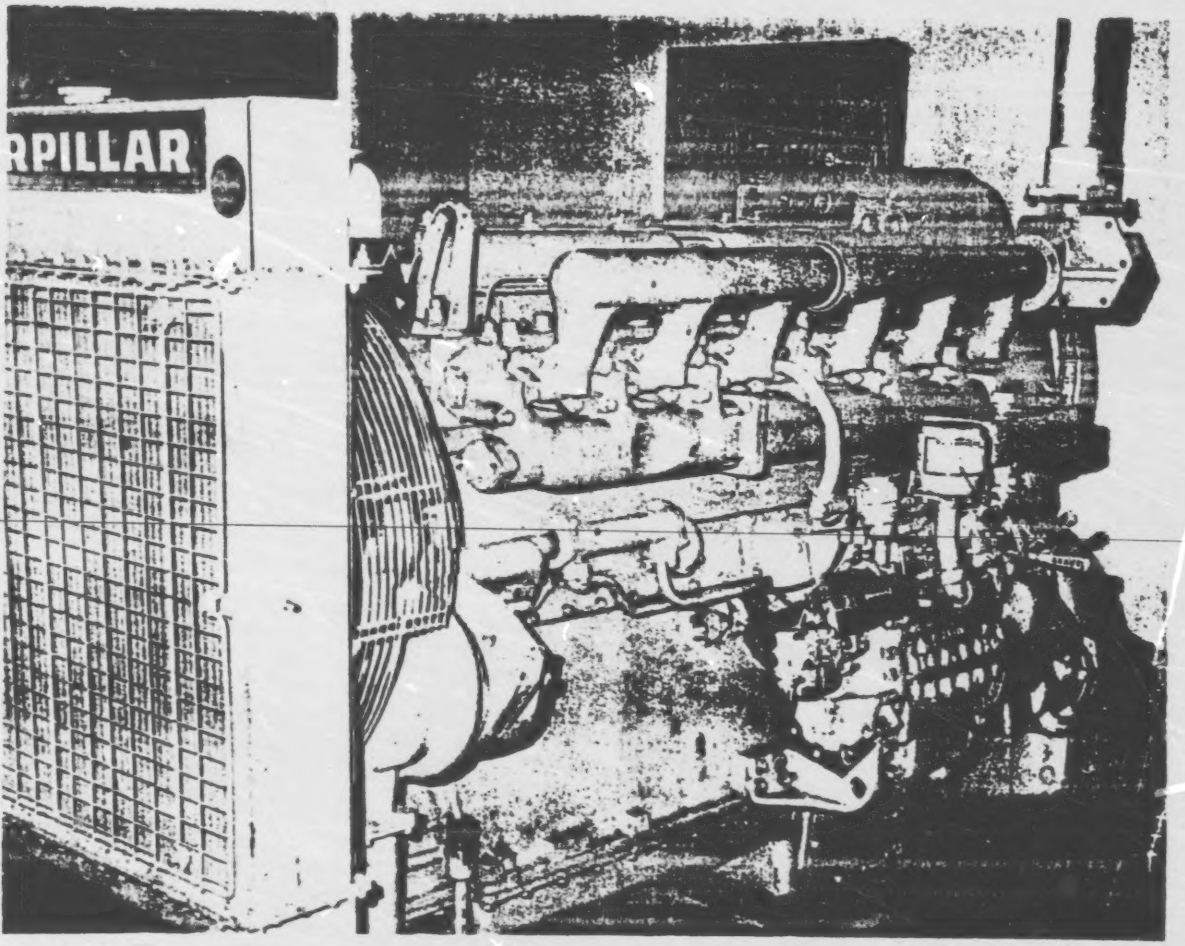


1. Water manifold.
2. Rocker arm.
3. Valve springs.
4. Fuel injection valve.
5. Air cleaner.
6. Compression release rod.
7. Push rod.
8. Connecting rod.
9. Oil filter.
10. Valve lifter.
11. Water pump.
12. By-pass valve.

81.341

Figure 9-3.—6-cylinder Caterpillar diesel engine front (cutaway view).

601



81.342

Figure 9-4.—Starting engine side of a 6-cylinder Caterpillar engine.

starting procedure of the engine you are working on, check with your leading petty officer or the manufacturer's manual.

FUEL INJECTION SYSTEM

The Caterpillar diesel engine uses the pump and nozzle injection system (fig. 9-6).

Each pump measures the amount of fuel to be injected into the particular cylinder, produces the pressure for its injection, and times the exact point of injection. The injection pump plunger is lifted by cam action and returned by spring action. The metering of fuel is varied by the plunger turning in the barrel. These plungers are turned by governor action through a rack which meshes with the gear segments on the bottom of the pump plungers. Each pump is interchangeable with other injection pumps mounted on the pump housing.

The capsule-type nozzle is widely used in Caterpillar diesel engines. (See fig. 9-7.) The capsule-type nozzle is a sealed unit; therefore it must be replaced when worn or damaged, although the tip opening may be cleaned with a

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special tool if clogged or dirty with carbon deposit.

The fuel is drawn from the tank by a gear-type transfer pump which delivers the fuel through filters into the fuel manifold in the fuel injection housing; from the fuel manifold, the fuel is supplied by separate passages to the individual fuel injection pumps. The fuel injection pumps deliver the proper amount of fuel through the fuel lines to the individual fuel injection valves at the proper time. From the injection valves the fuel enters the precombustion chambers. Ignition starts to take place in the precombustion chambers.

Removal of Injection Valves

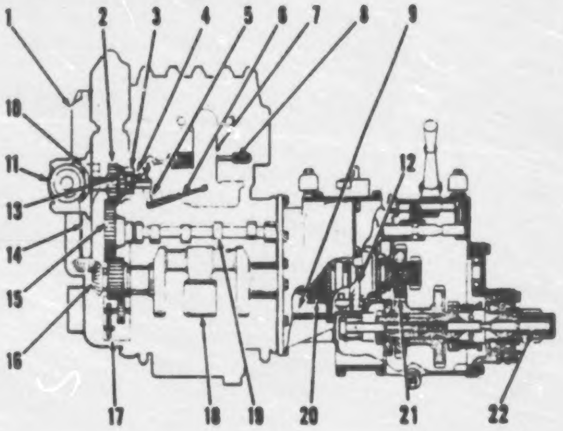
When there is a requirement for removal of injection valves from the engine, clean all dust and dirt from the injectors and adjacent area to prevent dirt from entering the fuel system. Disconnect the drain tube and fuel inlet line and remove the flange nuts that hold the injector valves in place. Be sure to seal the injector and fuel line openings to prevent foreign matter from entering. Refer to manufacturer's repair manuals for the proper procedures in testing and repair of injection valves.

When reinstalling fuel injectors or replacements, make sure there is no dirt on the end of the injector or on the seat. After wiping these parts and putting the injector in place, the flange nuts should be drawn down evenly. Tighten them only enough to prevent compression leaks from the cylinder.

Replacement of Injection Pumps

Caterpillar injection pumps are interchangeable between cylinders on a particular engine and also between engines having the same bore, no matter whether the engines have four or six cylinders. However, each fuel injection pump assembly is machined and lapped to such exact clearances between the plunger and barrel that they must be used, removed, and replaced as a unit.

In removing fuel injection pumps, take every precaution to prevent dirt from entering the pump or pump housing. Therefore, before disconnecting any fuel lines or removing the inspection plate on the pump assembly housing, clean the top and sides of the housing thoroughly.



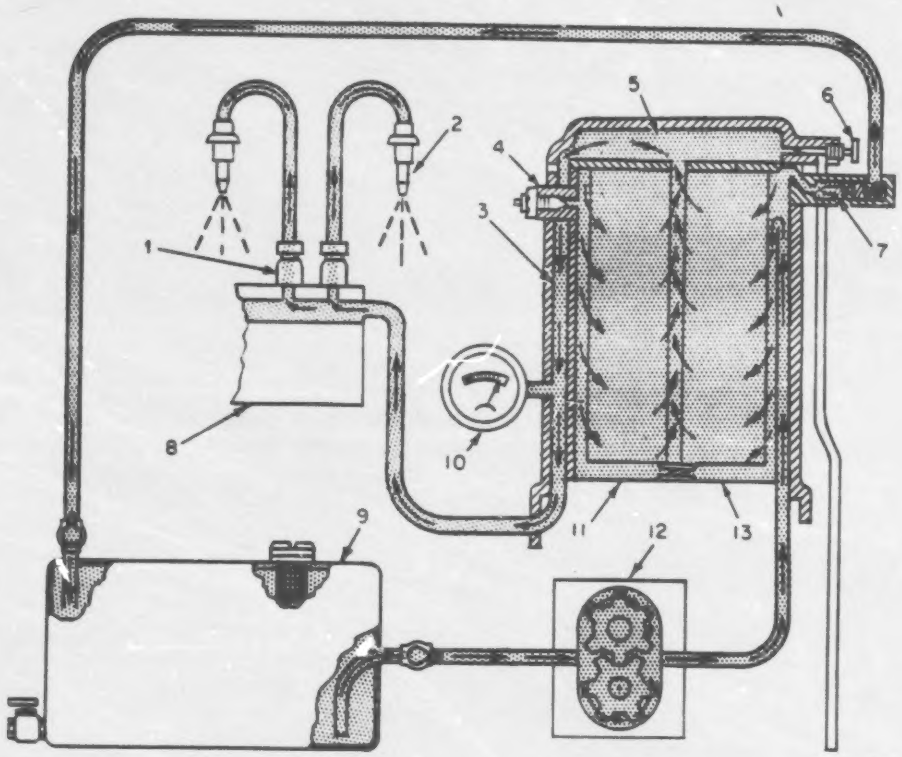
1. Magneto.
2. Governor drive gear.
3. Governor weight.
4. Governor control fork.
5. Control lever.
6. Linkage.
7. High idle control spring.
8. High idle adjusting nut.
9. Flywheel.
10. Impulse coupling.
11. Hand crank mechanism.
12. Clutch collar.
13. Governor sliding sleeve.
14. Magneto drive trunnion.
15. Camshaft gear.
16. Crankshaft gear.
17. Oil pump.
18. Crankshaft.
19. Camshaft.
20. Clutch.
21. Transmission.
22. Pinion.

81.343

Figure 9-5.—Clutch and transmission assemblies of a gasoline starting engine.

Start with the end pump of each bank when you are ready to remove them. With 4-cylinder engines there is only one bank of pumps, but with 6-cylinder engines the pumps are arranged in two banks of three each. The end pumps can be removed without disturbing the others. The center pump, for example two or five in a 6-cylinder arrangement, can be removed more easily if the pump next to it has been removed.

After disconnecting the fuel lines from the pumps, cover the openings immediately with the caps and plugs provided in the tool kit for this



1. Injection pump.
2. Injection valve.
3. Passage.
4. Lower vent.
5. Upper chamber.
6. Upper vent.
7. Bypass valve.
8. Housing.
9. Tank.
10. Gage.
11. Housing.
12. Transfer pump.
13. Lower chamber.

81.344

Figure 9-6.—Caterpillar fuel system.

purpose. Then, after removing the coupling, retaining plates, and rack (view A, fig. 9-8), take out the cap screws (view B), that hold the fuel injection pump clamps. Make sure the cap on the fuel outlet on top of the pump is in place while the pump is disconnected from the engine. Remove the clamps that hold the fuel injection pumps to the housing. Now, the pumps can be lifted from the housing.

Lift out the pumps individually, as shown in figure 9-9. At first, lift them straight up only enough to clear the dowel pins. Then reach through the inspection opening and hold the pump plunger to keep it from sliding out of the barrel. To remove the pump entirely, it will be necessary to shift the pump slightly to one side to free the plunger from the slot in the lifter yoke.

When installing a fuel injection pump, again be careful that the pump plunger does not slide out of the barrel. Slide the end of the plunger into the slot on the lifter; lower the pump on the dowel pins and fasten in place.

If the pump plunger should fall out, wash it thoroughly with clean diesel fuel and then replace it in the pump barrel. As a check against accidental nicks and scratches that will shorten the life of the pump, rotate the plunger gear segment to make sure that the plunger turns freely and does not bind.

To synchronize pump operation, turn the gears on the pump plungers until the marked tooth of each gear faces outward toward the pump rack. Replace the pump so that the marked teeth of the plunger gears engage with the marked rack teeth.

After sliding the rack into position, pull it out again to see that the marks are correctly aligned. Then fasten the racks with the retaining plates; install the coupling (fork) between the rack and the fuel pump slide bar; replace the inspection cover and connect the fuel lines.

Before starting the engine, bleed the fuel system to remove all air trapped in the fuel lines.

GOVERNOR OPERATION AND ADJUSTMENTS

The Caterpillar governor, like most governors used on diesels, is of the flyweight type (mechanical) and acts throughout the entire speed range of the engine. Once the desired speed is set by the position of the throttle, the governor acts automatically to maintain a relatively constant operating speed if the load changes. That is, all mechanical governors show a slight engine speed drop when a heavy load is first applied, and the engine will overspeed momentarily when the load is reduced. The throttle, connected to the governor by a suitable linkage, is merely a controlling device which adjusts the speed at which it then holds the engine.

Although the installation will vary with the engine models, most Caterpillar tractors have their governors vertically mounted and driven by the camshaft gear in the accessory housing in the front end of the injection pump housing. The throttle control is located where it is convenient for the operator. Figure 9-10 illustrates the working parts of a Caterpillar governor.

In OPERATION, the governor shaft is driven off the engine accessory drive gear. As the

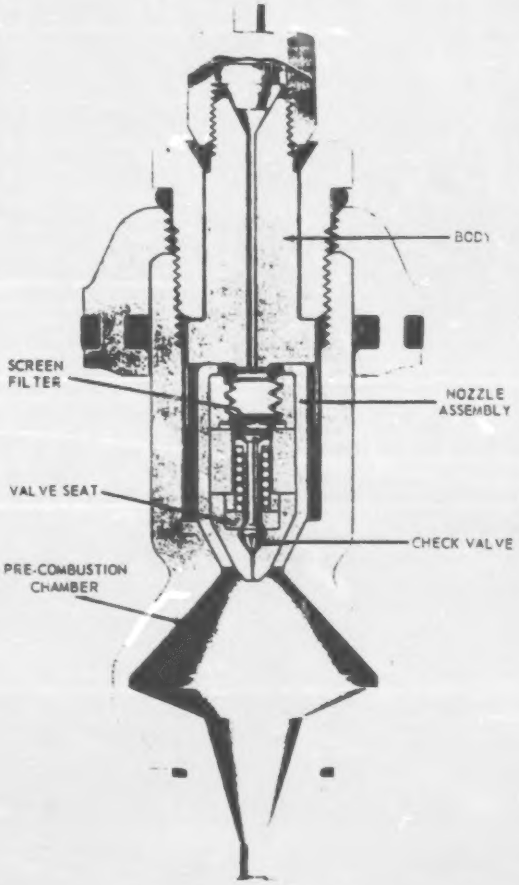


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Figure 9-7.—Capsule type fuel injection valve assembly.

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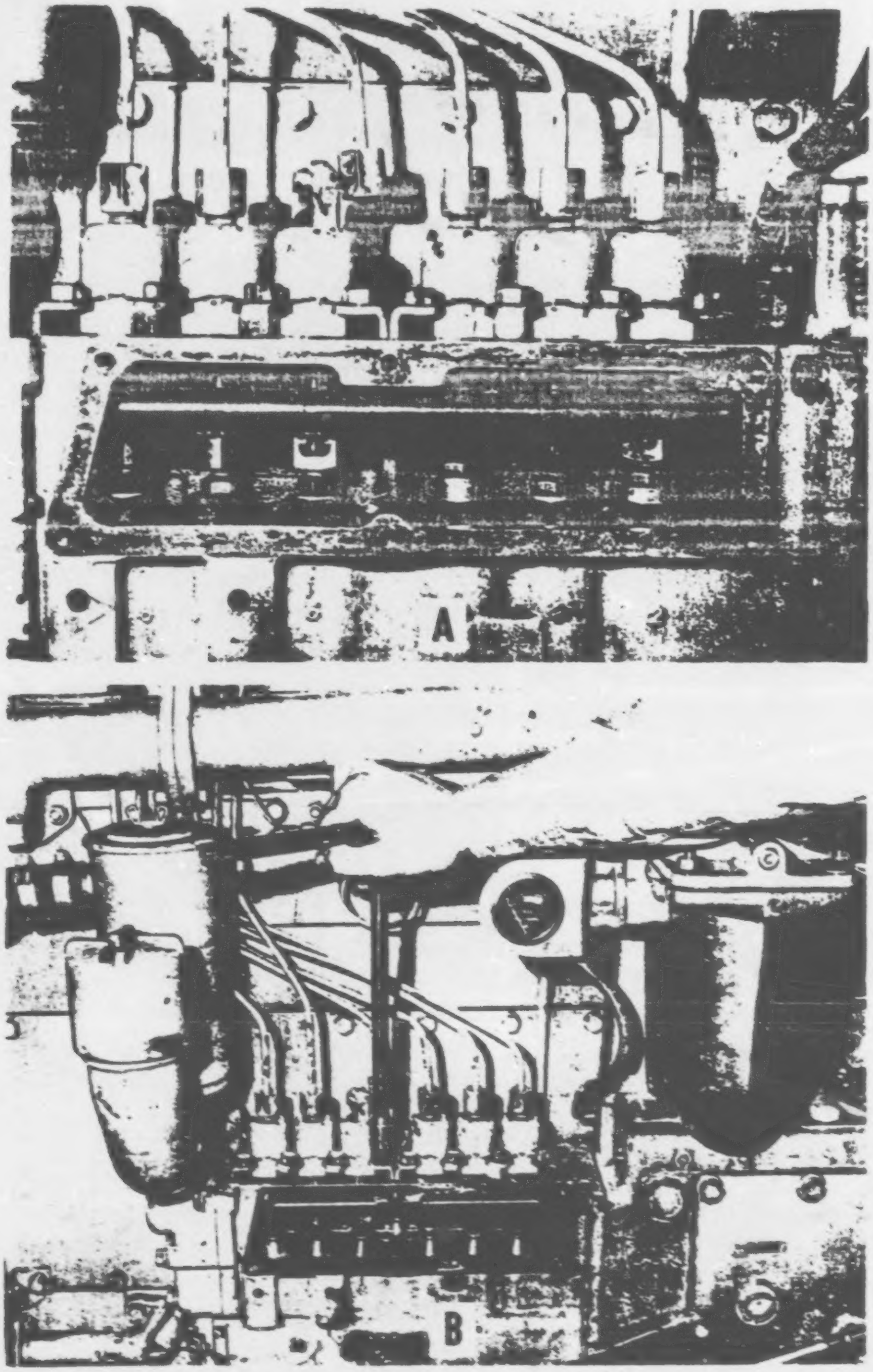

81.346

Figure 9-8.—Preparing to remove an injection pump from a Caterpillar diesel.

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engine speeds up, the flyweights (governor weights) hinged to the governor shaft swing out by centrifugal force. This action is opposed by the governor springs. The forces of the flyweights and governor springs act upon the slide bar to regulate the speed of the engine in accordance with the tension placed on the springs by the setting of the throttle. As the flyweights change their position with varying engine speeds, this movement is transmitted through the slide bar to the injection pump control rack. The control rack, in turn, rotates each pump plunger simultaneously to regulate the fuel delivered at the spray valves. Thus, as the operator changes the position of the throttle, the tension of the governor spring is changed, and the governor will maintain the engine speed called for by that particular throttle setting.

The governor is lubricated by oil from the engine lubricating system. At points where positive lubrication is necessary, such as bearings and bushings, oil is furnished under pressure through drilled passages in the housing or through tubes. Other parts of the governor are lubricated by the oil splash thrown off by the rotating parts.

Major adjustments are generally necessary only at the time the governor is completely disassembled, inspected, and repaired in the shop. This should be done by men who thoroughly understand the governor operation. However, it will sometimes be necessary to make idling and high-idle speed adjustments in the field. These adjustments can be made by removing the cover from the top of the governor (fig. 9-11) and turning the adjusting screws. The holes in the cover are serrated to act as retainers to prevent the screws from turning after the adjustment is made.

To make a low-idle speed adjustment put the engine speed control lever in the low-idle position. Turn the low-idle screw clockwise to decrease the speed or counterclockwise to increase the speed. The engine rpm can be checked with a tachometer at the drive connection on the hour meter as shown in figure 9-12.

In checking engine speed at the hour meter, remember that the tachometer drive shaft turns only at one-half engine speed. If, for example, a 450 rpm idling speed is desired, you should read 225 rpm on the hand tachometer.

In ADJUSTING THE HIGH-IDLE SPEED at the governor, see that the engine speed control lever is pulled all the way back when you check the engine speed. The adjustment should be as close as possible to the manufacturer's recommendations. For example, if the recommended high-idle speed is given as 1550 rpm, and you read 1280 rpm (640 rpm x 2) at the tachometer drive connection, the engine is running too slowly to develop its rated power with a full load. In this case, turn the high-idle speed adjusting screw counterclockwise to increase the speed.

If the engine runs too fast, turn the same screw clockwise to reduce the speed. Make only small corrections at a time. After each adjustment, close and open the throttle and recheck the speed. A recommended maximum speed of 1550 rpm will result in approximately a full-load speed of 1400 rpm when the normal speed drop (described later) is considered. A full-load speed of 100 rpm less than recommended maximum without a load is good insurance against possible damage from overspeeding the engine.

If it is necessary to adjust full-load speed more accurately, special governor setting fixtures are needed. With them, the maximum full-load speed can be adjusted without actually loading the engine. If these governor setting fixtures are available, make sure you know how to use them, and follow the manufacturer's manual concerning the installation and use of the fixtures.

LUBRICATION SYSTEM

The Caterpillar diesel engine is provided with a full force feed lubrication system, the principal components of which are the filters, oil cooler, and oil pump (fig. 9-13). The Caterpillar uses two types of oil pumps. One type consists of two auxiliary pump sections connected to screened suction cups located at the front and rear of the oil pan. The other type consists of three sets of gears. The forward set removes oil from the front of the crankcase, the afterset from the opposite end. These two sets of gears discharge the oil toward the center of the crankcase, while the center set of gears takes suction from this space and creates an oil pressure on the whole lubricating system. A regulating valve on the center gears raises or lowers the oil pressure and is accessible through the crankcase inspection plates. When the tractor is driven up or down steep hills, these pump sections or gear sets return accumulated oil from the low end of the crankcase to the center pump.

The oil pump forces the oil from the crankcase through the passages in the oil filter base to the oil cooler, which is located either in the front of the radiator in old models, or in the radiator shell in more recent ones. The oil cooler actually is a radiator in which oil is

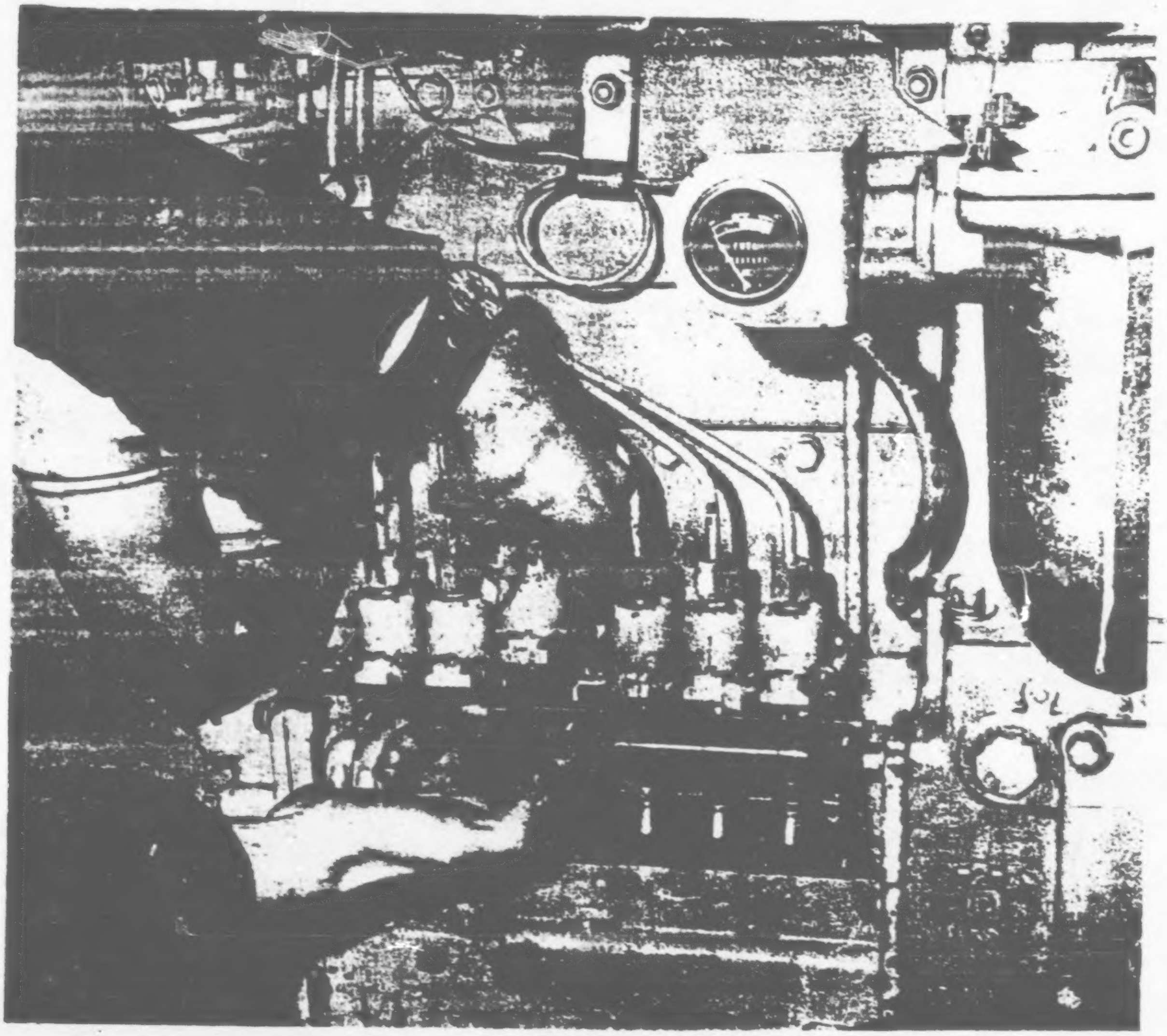

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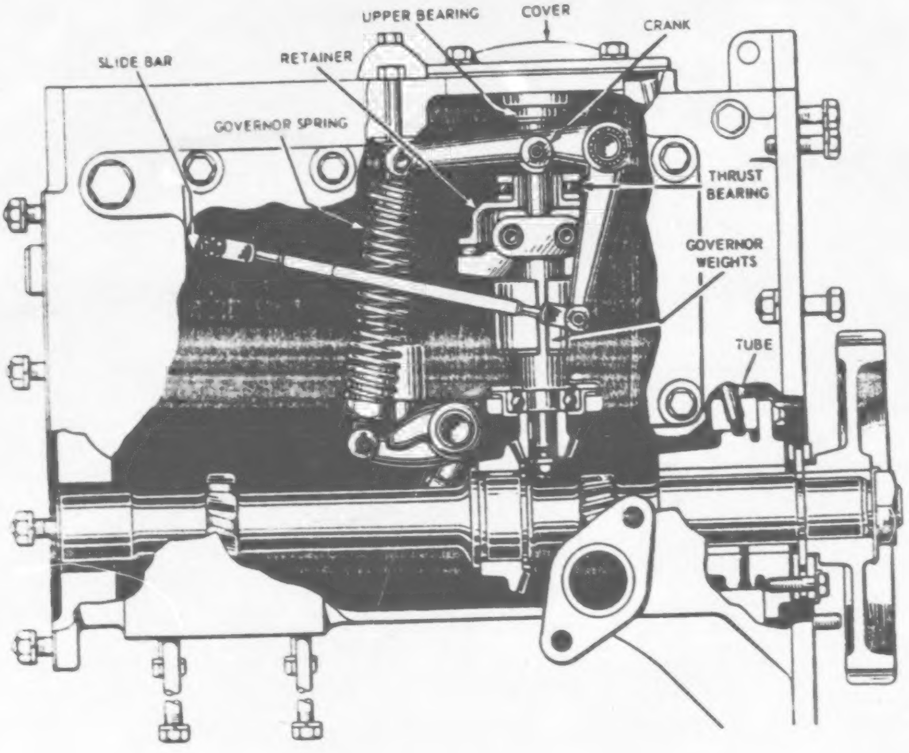
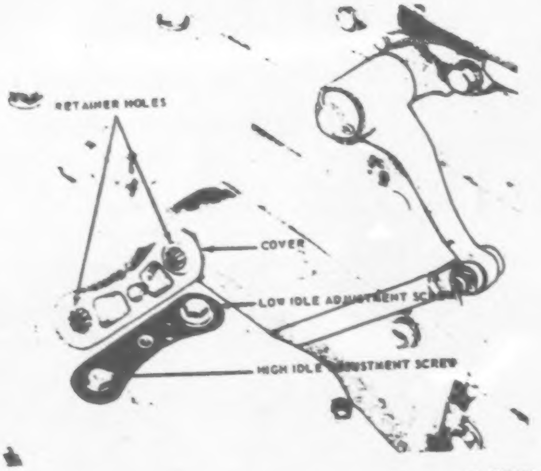
Figure 9-9.—Removing or replacing fuel injection pump on a 6-cylinder Caterpillar diesel.


UPPER BEARING
COVER
CRANK
SLIDE BAR
RETAINER
GOVERNOR SPRING
THRUST BEARING
GOVERNOR WEIGHTS
TUBE

2.64X

Figure 9-10.—Cross section of a Caterpillar governor.


RETAINER HOLES
COVER
LOW IDLE ADJUSTMENT SCREW
HIGH IDLE ADJUSTMENT SCREW

2.65X

Figure 9-11.—Governor adjustments.

circulated through the core instead of water as in the conventional radiator. From the cooler, the oil is forced back into the filter. Current model caterpillar engines employ a heat exchanger type oil cooler in which the oil is cooled by the water in the cooling system. Fairly recent model Caterpillars have a full flow-type filter with a replaceable element; the older models used a bypass-type filter with a metal element. From the filter the oil passes into the oil manifold and is distributed to the engine parts. In case the oil filter is clogged, the oil is bypassed through a valve in the filter housing directly to the engine.

COOLING SYSTEM

The Caterpillar cooling system, like most water cooled systems, consists of the water pump, water manifolds, temperature regulators or thermostats, overflow valve, radiator, fan, and connecting pipes and hoses. The gear-driven

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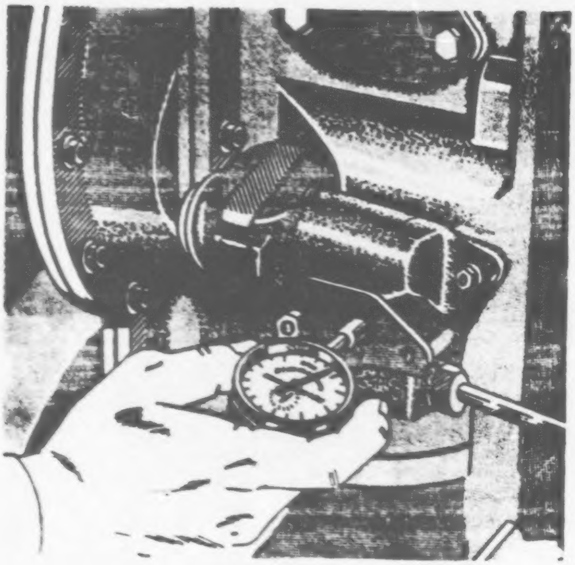

2.66
Figure 9-12.—Checking engine speed with hand tachometer.

centrifugal water pump, which is located on the left side of the engine, circulates water through both the gasoline starting engine and the diesel engine. The pump forces the water to the cylinder block, where it is directed against the precombustion chambers. From the cylinder block the water passes through an external return manifold. Two temperature regulators, or thermostats, are mounted in the forward end of the manifold and limit the flow of water to the radiator in order to maintain the proper engine temperature. When the engine is cold, the thermostats are closed, and the water is bypassed to the water pump by a bypass tube. After the engine warms up, the thermostats open, and the water flows through the radiator, into the pump to complete the cycle. An overflow valve located on the expansion tank of the radiator prevents overflow of the water when the tractor is operated on steep surfaces. The cooling system has a fan, which is driven by two V-belts around a pulley on the crankshaft. The normal operating temperature of the Caterpillar engine is 170° to 180° F.

Dirt between the tubes of the radiator and oil cooler may cause the engine to run hot. They should be cleaned when a PM inspection is done on the machine. You may wash, brush or blow the dirt out with whichever method is available and most effective. Wash or blow opposite to the direction of air flow.

The cooling system should be drained occasionally to remove dirt and sediment which accumulates. The draining should be done at the end of the day's operation, when the foreign material is in suspension and will easily drain with the liquid.

If the fan belts are operated too loose, they will slap against the pulleys, causing unnecessary wear to the belts and possible slipping to the extent that the engine will overheat. If the belts are too tight, unnecessary stresses are placed upon the fan bearings and belts, which will shorten the life of both. Correct adjustment exists when the belts can be pushed inward approximately 1 1/2 inches at a point midway between two pulleys. When belts need replacing they should be replaced as a matched set—never only one.

HOUR METER

The Caterpillar tractor is equipped with an HOUR METER (fig. 9-14). The name of this device is misleading, because it does not record clock hours. The hour meter "counts" the revolutions of the crankshaft, registering an HOUR when the crankshaft has completed a certain number of revolutions. That is, when the crankshaft has turned as many times as in an hour's normal operating speed, the indicator on the meter advances one number.

The hour meter is usually located on the right side of the engine, near the bottom of the governor housing. It is usually mechanically driven from the fuel injection pump. It tells when to service your equipment according to the manufacturer's manual.

It may well be said that the hour meter is the MAINTENANCE WATCHMAN, not only of the Caterpillar, but of all diesel engines powering heavy duty equipment.

INTERNATIONAL DIESEL ENGINES

Most International diesel engines found in the Navy today are of the direct diesel starting type. You may find some earlier models that start like conventional gasoline engines; after a short warmup period on gasoline, they are converted to full diesel operation by simply shifting the compression release lever from the starting to the running position. For proper

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CHAPTER 15

PREVENTIVE MAINTENANCE

Maintenance is the care exercised and the work performed to retain vehicles and equipment in safe and serviceable operating condition during their normal service life. The purpose of the Navy's Preventive Maintenance program is to effect economy and dependability in the use of equipment and to insure continuity of operation. It is not intended that vehicles be maintained in a like-new condition during this period.

The maintenance required on private automobiles is similar to that required on Navy equipment. (1) The car owner performs a before operation inspection. He visually checks the safety of the vehicle to assure himself that he has sufficient fuel, oil, and coolant before starting. If the car uses oil or gasoline in excessive amounts, he is usually aware of the fact and has to decide on the maximum amount he will spend on repairs. (2) The owner has the car lubricated periodically. This lubrication job includes inspection of items not checked daily by the owner and the lubrication man informs the owner of any defects he finds so that they may be corrected. When all the minor defects are corrected, as they occur, very few maintenance problems develop.

These two inspections, the daily check by the owner and the lubrication service at the prescribed intervals, are the two most important and basic phases of a sound Preventive Maintenance Program. Further, most conscientious owners have a tune-up performed on his car at various times to keep it in top operating condition for maximum efficiency. Most owners do not keep a complete record of the maintenance performed, while the Navy, because of the number of vehicles it maintains must have a standard maintenance program to insure maximum efficiency from Navy equipment.

The operator is required to perform a before operation inspection and record his findings on the proper form. After a specified number of operating hours or length of time, an intermediate inspection is required. An intermediate inspection includes a complete lubrication of the equipment and is completed by personnel assigned to the maintenance section. A more thorough major inspection is required periodically to insure long equipment life.

Before operation, intermediate and major inspections are required and performed on equipment when it has been assigned to one using organization. If the equipment is old, involved in an accident, or transferred to another organization, a complete technical inspection is required.

A complete technical inspection will indicate all repairs and the cost to complete the repairs. The maximum amount of money that can be economically expended is governed by regulation. The equipment will be salvaged and replaced if the cost of repair is considered excessive.

As a Construction Mechanic, you will be interested in the types of inspection and preventive maintenance scheduling. As a repairman, you will use certain forms authorized by existing regulations in performing inspections and maintaining cost records. Therefore, it is necessary for you to become familiar with certain basic jobs and their related duties.

The primary function of the PM clerk is the scheduling of vehicles and equipment for PM service checks. The production dispatcher schedules and expedites the flow of equipment from the time of its arrival in the shop through the work centers until the required maintenance or repairs have been completed. The inspector must be a top-notch mechanic capable of accurately determining the nature and extent of repairs required on equipment, and be able to determine whether deficiencies reported require immediate attention or can be delayed until next scheduled PM service. The cost accounting clerk is responsible for keeping a record of the labor and parts charged to each piece of equipment, so that a proper cost allocation can be made. The forms used are generally the same for both the construction and public works maintenance facility.

OPERATOR'S PREVENTIVE MAINTENANCE

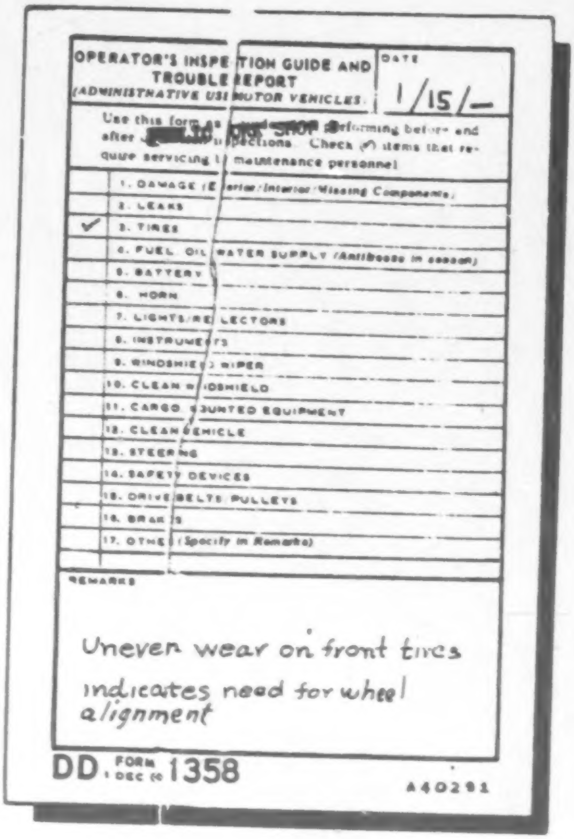
The operator's PM check is the first line of defense against vehicle wear, failure or damage. He should inspect his vehicle or equipment systematically before and after operation so that defects may be discovered before they result in serious damage or failure. The first things that the operator should check are the oil, water, battery, and tires. The operator should also make sure that the brakes are in proper working order. If the vehicle or equipment is equipped with air brakes he should make sure that the air bleeder valves are turned off and that the air system will attain normal operating pressures.

VEHICLE OPERATOR'S INSPECTION GUIDE AND TROUBLE REPORT (DD 1358)

Defects discovered during operator's inspections or during operation of the vehicle are recorded on the Operator's Inspection Guide and Trouble Report-DD Form 1358 (fig. 15-1) and reported as soon as operation has ceased. The operator should stop operation immediately if a deficiency is observed that could damage the vehicle or render it unsafe to operate.

The Operator's Inspection Guide and Trouble Report indicates the items that the operator should inspect before and after operation of the vehicle. This form also serves to transmit information to the maintenance ship regarding deficiencies detected during inspections or operation of the vehicle. When the operator is assigned to a vehicle, the operations dispatcher (or, at smaller facilities, the EO chief) issues the form to the operator. The operator should indicate by a checkmark any item that does not function properly. The "Remarks" space may be used for items not listed, or for additional information concerning deficiencies indicated by a checkmark; he should also place the vehicle number in the remarks space. The operator turns in the form to the operations dispatcher.

The operations dispatcher forwards the forms that indicate deficiences to the maintenance dispatcher. The maintenance dispatcher refers the DD 1358 to the inspector. The inspector determines if the deficiencies noted on the forms require immediate attention or if the corrective action may be safely deferred until the next scheduled PM inspection. If the corrective action is deferred, the DD 1358 is attached to the Preventive Maintenance Record Card (discussed later in this chapter).



OPERATOR'S INSPECTION GUIDE AND TROUBLE REPORT
(ADMINISTRATIVE USE MOTOR VEHICLES)

DATE 1/15/—

Use this form as [illegible] performing before and after [illegible] inspections. Check (✓) items that require servicing by maintenance personnel

☐ 1. DAMAGE (Exterior/Interior/Missing Components)
☐ 2. LEAKS
☑ 3. TIRES
☐ 4. FUEL OIL WATER SUPPLY (Antifreeze in season)
☐ 5. BATTERY
☐ 6. HORN
☐ 7. LIGHTS/REFLECTORS
☐ 8. INSTRUMENTS
☐ 9. WINDSHIELD WIPER
☐ 10. CLEAN WINDSHIELD
☐ 11. CARGO MOUNTED EQUIPMENT
☐ 12. CLEAN VEHICLE
☐ 13. STEERING
☐ 14. SAFETY DEVICES
☐ 15. DRIVE BELTS PULLEYS
☐ 16. BRAKES
☐ 17. OTHER (Specify in Remarks)

REMARKS

Uneven wear on front tires indicates need for wheel alignment

DD FORM 1 DEC 66 1358

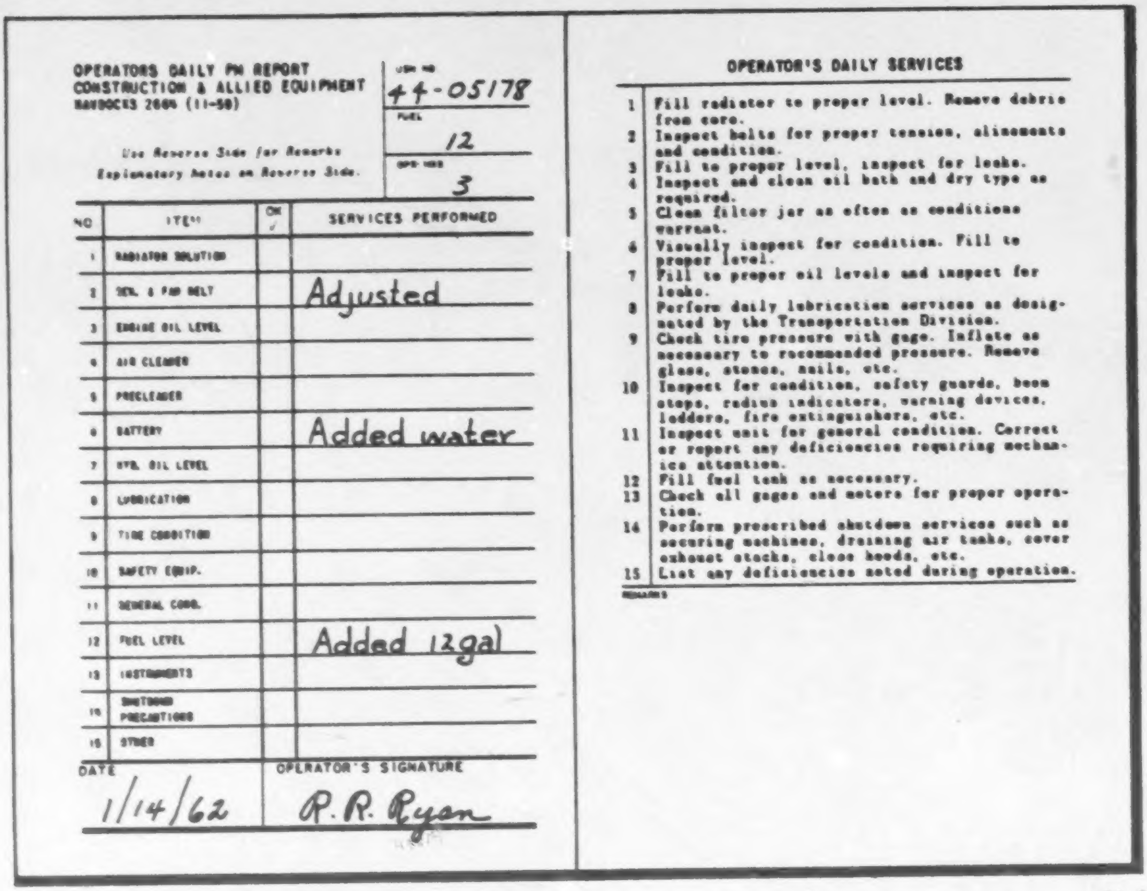
A40291

29.50

Figure 15-1.—Operator's Inspection Guide and Trouble Report—DD1358.

EQUIPMENT OPERATOR'S DAILY PM REPORT (NAVDOCKS 2664)

The form used by operators of Construction and allied equipment as a guide when performing daily PM services is the Operator's Daily PM Report, Construction and Allied Equipment, NavDocks 2664 (fig. 15-2). The equipment



OPERATORS DAILY PM REPORT
CONSTRUCTION & ALLIED EQUIPMENT
NAVDOCKS 2664 (11-58)

Use Reverse Side for Remarks
Explanatory Notes on Reverse Side.

USN NO 44-05178
FUEL 12
OPR HRS 3

NO	ITEM	OK ✓	SERVICES PERFORMED
1	RADIATOR SOLUTION		
2	GEN. & FAN BELT		Adjusted
3	ENGINE OIL LEVEL		
4	AIR CLEANER		
5	PRECLEANER		
6	BATTERY		Added water
7	HYD. OIL LEVEL		
8	LUBRICATION		
9	TIRE CONDITION		
10	SAFETY EQUIP.		
11	GENERAL COND.		
12	FUEL LEVEL		Added 12gal
13	INSTRUMENTS		
14	SHUTDOWN PRECAUTIONS		
15	OTHER		

DATE 1/14/62
OPERATOR'S SIGNATURE R. R. Ryan

OPERATOR'S DAILY SERVICES

1 Fill radiator to proper level. Remove debris from core.
2 Inspect belts for proper tension, alinements and condition.
3 Fill to proper level, inspect for leaks.
4 Inspect and clean oil bath and dry type as required.
5 Clean filter jar as often as conditions warrant.
6 Visually inspect for condition. Fill to proper level.
7 Fill to proper oil levels and inspect for leaks.
8 Perform daily lubrication services as designated by the Transportation Division.
9 Check tire pressure with gage. Inflate as necessary to recommended pressure. Remove glass, stones, nails, etc.
10 Inspect for condition, safety guards, boom stops, radius indicators, warning devices, ladders, fire extinguishers, etc.
11 Inspect unit for general condition. Correct or report any deficiencies requiring mechanics attention.
12 Fill fuel tank as necessary.
13 Check all gages and meters for proper operation.
14 Perform prescribed shutdown services such as securing machines, draining air tanks, cover exhaust stacks, close hoods, etc.
15 List any deficiencies noted during operation.

REMARKS

81.323

Figure 15-2.—Operators DAILY PM Report, Construction and Allied Equipment, NavDocks 2664.

operator receives the form from the operations dispatcher when the equipment is assigned. The operator goes through the same procedure as that with form DD 1358 of checking and noting malfunctions on the form. The operator shall return the form to the operations dispatcher at the end of the working day if there are any entries on the form. The form is then forwarded to the maintenance dispatcher for further processing. The maintenance dispatcher reviews the entries on the form and, in consultation with the inspector, determines the action which will be taken. Repairs are scheduled if there are items requiring immediate attention.

MAINTENANCE RECORDS AND REPORTS

Each vehicle and other piece of equipment has a history jacket that contains records and reports which supply information on its condition. They are used to review the history of its maintenance, determine its efficiency, and estimate the cost of its future operation.

To obtain accurate information and reports, the Naval Facilities Engineering Command (NAVFAC) has revised some forms and developed the STINGER system to determine better utilization of equipment.

The STINGER analysis office at CBC, Port Hueneme, California, is charged with providing rapid analysis to enable SEABEE and Navy decision makers to accurately and swiftly deploy sufficient manpower with adequate equipment and supplies to respond to any contingency. It is directly responsible to the Commander, Naval Facilities Engineering Command. STINGER stands for Seabee Tactically Installed, Navy Generated, Engineer Resources.

These files are maintained by a qualified office force. You may be given such office duty so you should learn to handle these forms. The forms which will be of concern to you as a CM3 or 2 are the Equipment Work Order (EWO), NavFac Form 6-11200/41, the Shop Repair Order (SRO), NavFac Form 9-11200/3A, and Continuation Sheet, NavFac Form 9-11200/3B, the Preventive Maintenance Record Card, NavDocks 1949, the Preventive Maintenance Service and Inspection Record, NavDocks 11200/5, the Daily Fuel Issue Report, NavFac Form 6-11200/42, the Monthly Fuel Usage Data, NavFac Form 6-11200/43, and the Monthly Fuel Report, NavFac Form 6-11200/44. They must be used and filled out in accordance with the quidelines set forth in the most current NAVFAC, COMCBLANT, and COMCBPAC 11200 series instructions. These forms are discussed in the following sections.

EQUIPMENT WORK ORDER (EWO). SHOP REPAIR ORDER (SRO), AND CONTINUATION SHEET

The Equipment Work Order (EWO) (fig. 15-3), Shop Repair Order (SRO) (fig. 15-4), and Continuation Sheet (fig. 15-5) are the sole authority to perform work in the equipment repair shops in the following categories:

1. Each time labor ormaterials are expended on scheduled maintenance, interim repairs, modernization, and alteration of equipment.
2. Exception—Repairs that do not exceed three tenths (.3) hour or require parts.
3. In all cases, equipment to be worked on must be accompanied by DD Form 1358 (fig. 15.1) or NavDocks 2664 (fig. 15-2), as appropriate.
4. Equipment having a primary and secondary unit, as in the case of asphalt distributors, twin engine scrapers, etc., dictates that both miles and hours be recorded. For example, the forward engine and pan of a twin engined scraper is considered the primary unit while the rear engine and its power train is considered the secondary unit. Further, on all others, that portion of the machine which was intended to perform the end use (such as the mixer portion of a transit mixer) must be considered the primary unit, while the carrier unit must be considered the secondary unit.

The "Equipment Work Order" (EWO), Navfac Form 6-11200/41, illustrated in figure 15-3, has been designed specifically for use by the Naval Construction Forces, Special Operational Units, and Naval Construction Schools. However, lack of adequate facilities in many instances contributes to the necessity of having maintenance performed in Public Works facilities or in the Construction Equipment Department (CED) repair shop of the Construction Battalion Centers. To avoid having to transcribe information from the "Shop Repair Order," NavFac Form 9-11200/3A and its continuation sheet, NavFac Form 9-11200/3B (figs. 15-4 and 15-5), after equipment repairs are completed at Public Works facilities or CED repair shops, more information has been added to the EWO. All facilities can now use the EWO for repair of equipment belonging to the Naval Construction Forces, Naval Construction Schools, and Special Operational Units.

NOTE: Some NavFac forms are identified by the term "NavDocks" followed by the form number. This is due to a change in name of the activity which is not yet reflected on all the forms. So remember that the two identifying terms refer to the same numbered form. On some NavSup forms you will also see the term NavSandA used, and the same situation applies here.

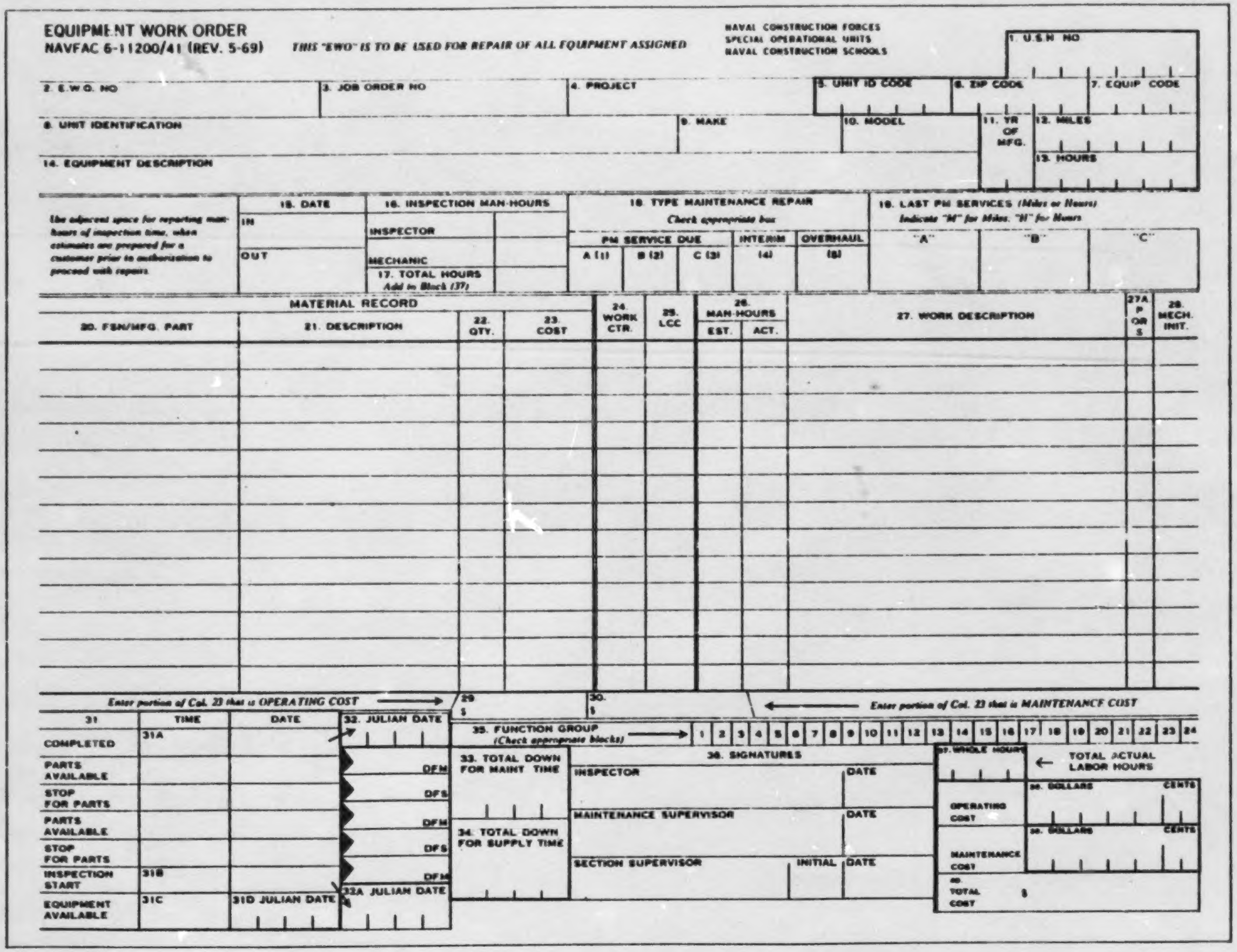
FUEL REPORTS

A "Daily fuel Issue Report," NavFac Form 6-11200/42 (fig. 15-6), is recommended to all cognizant activities as a concise, uniform method of providing fuel and oil usage data by USN number. Upon receipt of the completed "Daily Fuel Issue Report," the transportation dispatcher should transfer the information on it to the "Monthly Fuel Usage Data," report, NavFac Form 6-11200/43, which in turn is used to accumulate the data required for preparation of the "Monthly Fuel Report," NavFac Form 6-11200/44 (figs. 15-7 and 15-8). The "Monthly Fuel Usage Data" report also provides fuel issue totals to the Supply Officer on a daily basis.

The above forms each provide information that is used in the STINGER system.

PREVENTIVE MAINTENANCE RECORD CARD

A PM Record Card NavDocks 1949 (fig. 15-9) is maintained for each vehicle and piece of equipment for controlling PM services and



EQUIPMENT WORK ORDER
NAVFAC 6-11200/41 (REV. 5-69)

THIS "EWO" IS TO BE USED FOR REPAIR OF ALL EQUIPMENT ASSIGNED

NAVAL CONSTRUCTION FORCES
SPECIAL OPERATIONAL UNITS
NAVAL CONSTRUCTION SCHOOLS

						1. U.S.N. NO
2. E.W.O. NO	3. JOB ORDER NO	4. PROJECT	5. UNIT ID CODE	6. ZIP CODE		7. EQUIP CODE
8. UNIT IDENTIFICATION		9. MAKE	10. MODEL	11. YR OF MFG.	12. MILES	
14. EQUIPMENT DESCRIPTION					13. HOURS	

Use adjacent space for reporting man-hours of inspection time, when estimates are prepared for a customer prior to authorization to proceed with repairs	15. DATE IN OUT	16. INSPECTION MAN-HOURS INSPECTOR MECHANIC 17. TOTAL HOURS *Add to Block (37)*	18. TYPE MAINTENANCE REPAIR *Check appropriate box* PM SERVICE DUE: A (1) B (2) C (3) INTERIM (4) OVERHAUL (5)	19. LAST PM SERVICES *(Miles or Hours)* *Indicate "M" for Miles, "H" for Hours* "A" "B" "C"

MATERIAL RECORD										
20. FSN/MFG. PART	21. DESCRIPTION	22. QTY.	23. COST	24. WORK CTR.	25. LCC	26. MAN-HOURS EST.	26. MAN-HOURS ACT.	27. WORK DESCRIPTION	27A P OR S	28. MECH. INIT.

Enter portion of Col. 23 that is OPERATING COST → 29 $

30. $ ← *Enter portion of Col. 23 that is MAINTENANCE COST*

31	TIME	DATE	32. JULIAN DATE
COMPLETED	31A		
PARTS AVAILABLE			DFM
STOP FOR PARTS			DFS
PARTS AVAILABLE			DFM
STOP FOR PARTS			DFS
INSPECTION START	31B		DFM
EQUIPMENT AVAILABLE	31C	31D JULIAN DATE	32A JULIAN DATE

35. FUNCTION GROUP *(Check appropriate blocks)* → 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24

33. TOTAL DOWN FOR MAINT TIME

34. TOTAL DOWN FOR SUPPLY TIME

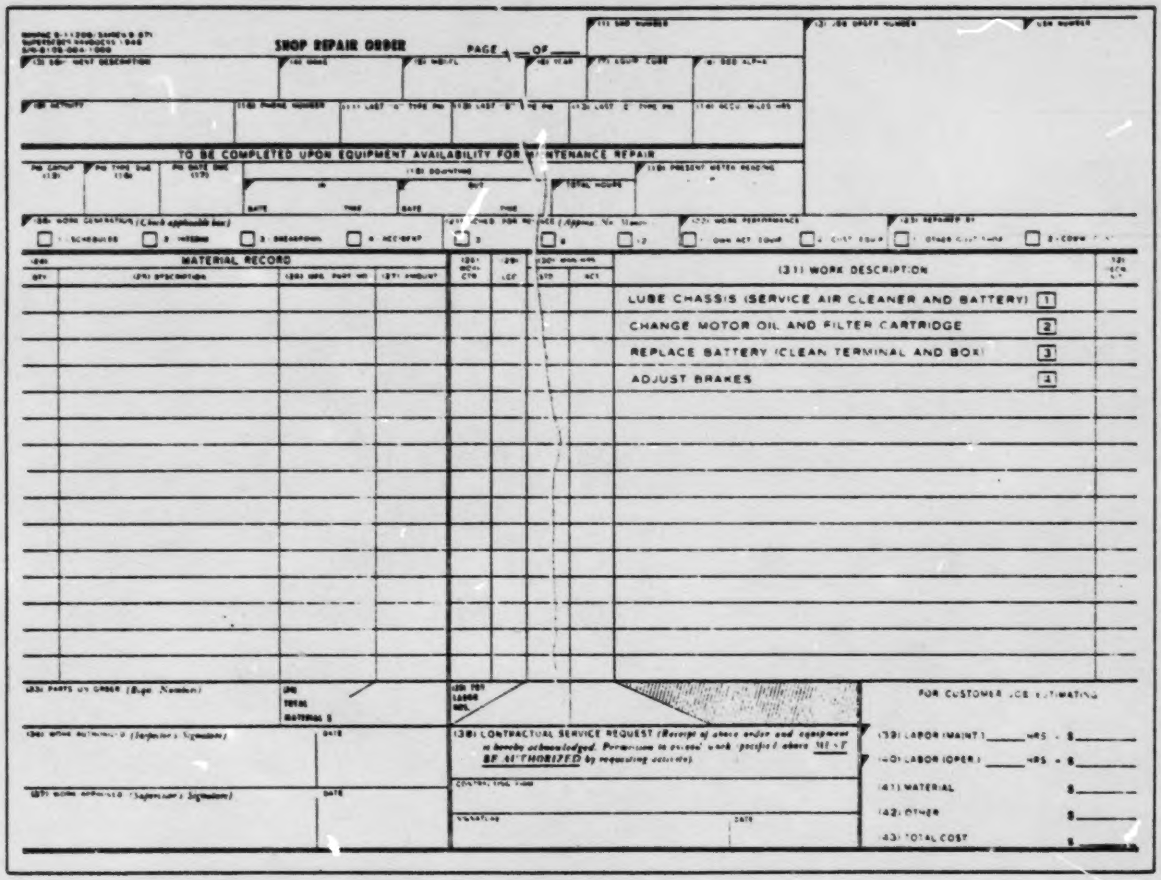
36. SIGNATURES
INSPECTOR — DATE
MAINTENANCE SUPERVISOR — DATE
SECTION SUPERVISOR — INITIAL — DATE

37. WHOLE HOURS ← TOTAL ACTUAL LABOR HOURS

OPERATING COST	38. DOLLARS	CENTS
MAINTENANCE COST	39. DOLLARS	CENTS
40. TOTAL COST	$	

2.400

Figure 15-3.—Equipment Work Order, NavFac Form 6-11200/41.



SHOP REPAIR ORDER PAGE ___ OF ___

TO BE COMPLETED UPON EQUIPMENT AVAILABILITY FOR MAINTENANCE REPAIR

MATERIAL RECORD

(31) WORK DESCRIPTION

LUBE CHASSIS (SERVICE AIR CLEANER AND BATTERY) 1

CHANGE MOTOR OIL AND FILTER CARTRIDGE 2

REPLACE BATTERY (CLEAN TERMINAL AND BOX) 3

ADJUST BRAKES 4

(38) CONTRACTUAL SERVICE REQUEST (*Receipt of above order and equipment is hereby acknowledged. Permission to exceed work specified above MUST BE AUTHORIZED by requesting activity*)

FOR CUSTOMER JOB ESTIMATING

(39) LABOR (MAINT.) ______ HRS = $______

(40) LABOR (OPER.) ______ HRS = $______

(41) MATERIAL $______

(42) OTHER $______

(43) TOTAL COST $______

2.8.1

Figure 15-4.—Shop Repair Order, NavFac Form 9-11200/3A.

recording cumulative miles or operating hours since the last PM. Each time a vehicle or piece of equipment is serviced, the PM Record Card should be reviewed to determine if the estimated annual utilization is reasonably accurate. If the odometer readings indicate that the vehicle is not accumulating mileage at the rate necessary to coincide with the original estimate made for PM service scheduling purposes, the figure for estimated annual mileage should be revised and the vehicle reassigned to a PM service group that corresponds to the revised annual mileage estimate. If a piece of equipment is not being utilized at the estimated rate, in terms of operating hours, it should be placed in a group which coincides with the newly determined PM period.

PREVENTIVE MAINTENANCE SERVICE INSPECTION RECORD

The Preventive Maintenance Service Inspection Record (fig. 15-10), NavDocks 11200/5, is an adhesive type sticker which is placed on the windshield, dash or other conspicuous section of the equipment or vehicle after the PM service is performed. The basic purpose of the form is to remind the operator of the date the equipment is scheduled for the next PM service. The form also provides information concerning the dates of the last oil and filter change and lubrication.

SCHEDULED PREVENTIVE MAINTENANCE (AUTOMOTIVE)

According to an interim change to Management of Transportation Equipment. NAVDOCKS P-300, the automotive preventive maintenance program has been modified. The policy on the program, current as of January 1970, is reflected in the following sections.

SCHEDULED INSPECTION AND SERVICES

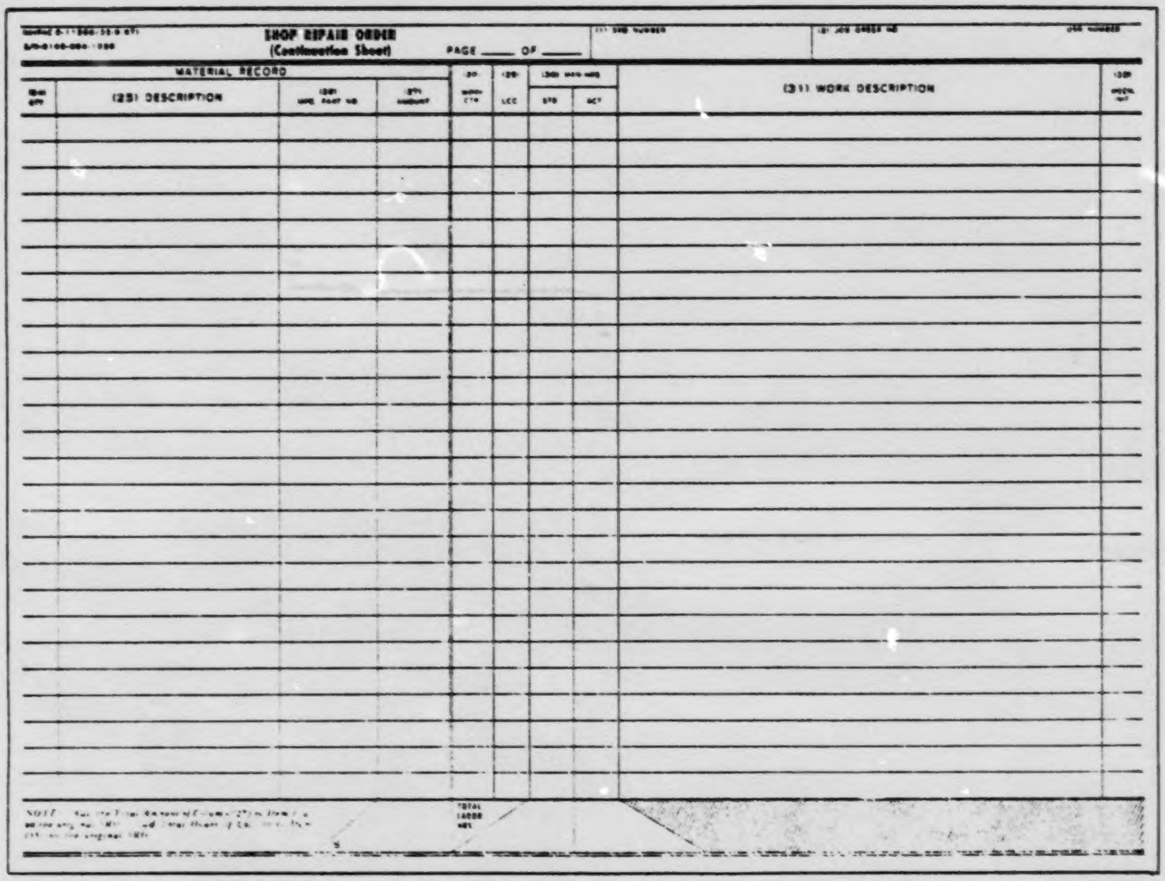
Vehicles are inspected periodically by qualified automotive inspection personnel for safety and serviceability.

Safety

Each motor vehicle must be inspected for safety at intervals not to exceed six months or 6,000 miles, whichever occurs first. To avoid unnecessary downtime, the safety inspection must be performed at the time of the scheduled serviceability inspection in accordance with the manufacturer's recommendations. The safety inspection must include all the items set forth in the Motor Vehicle Safety Inspection Checklist and correction of any deficiencies uncovered by the inspection before returning the vehicle to an operational status.

Serviceability

In addition to the safety inspection, vehicles must be inspected and serviced in accordance with the manufacturer's prescribed services and service intervals, i.e., miles or time as set forth in their shop manual and lubrication



SHOP REPAIR ORDER
(Continuation Sheet) PAGE ____ OF ____

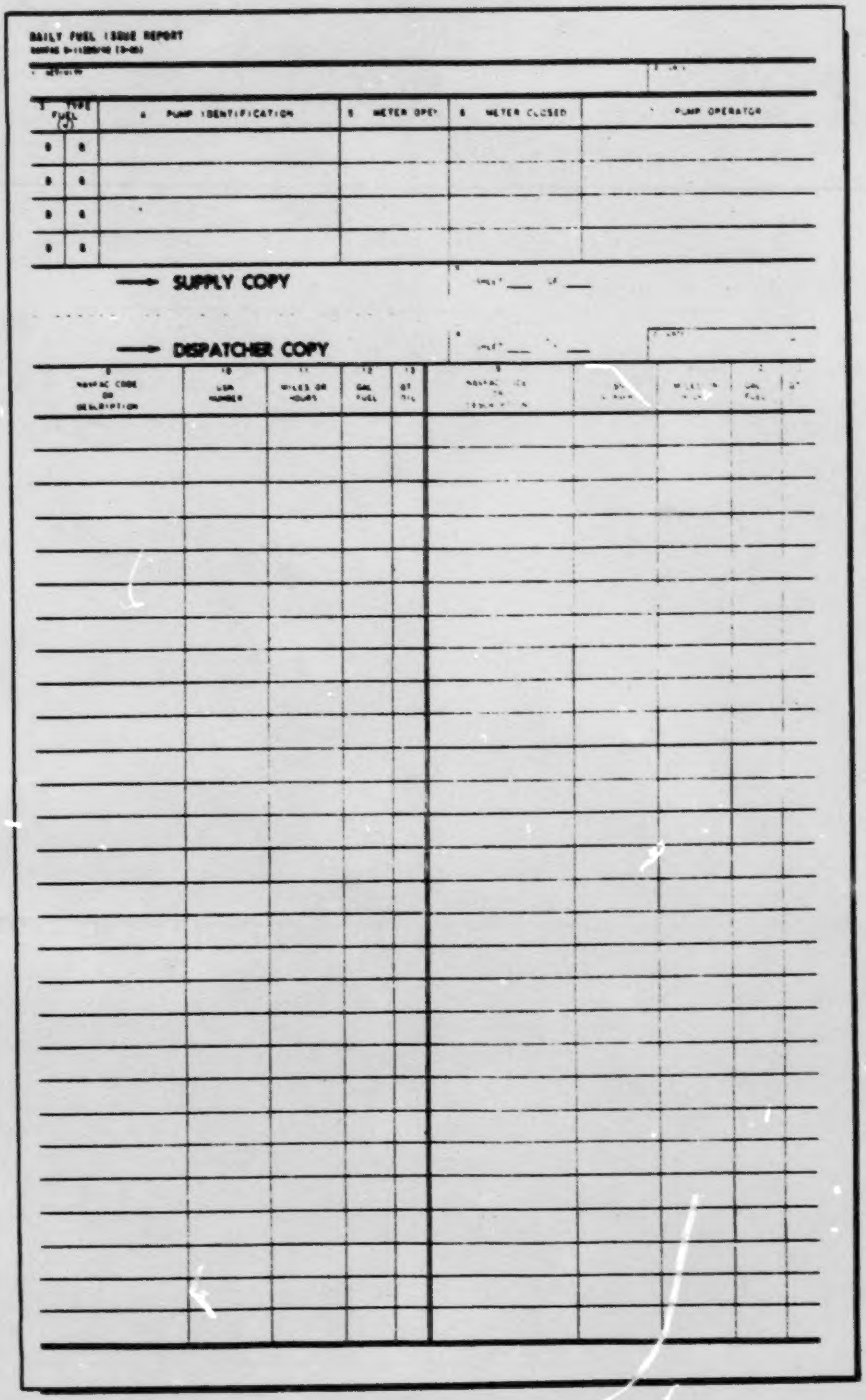
MATERIAL RECORD

(25) DESCRIPTION

(31) WORK DESCRIPTION

2.8.2

Figure 15-5.—Shop Repair Order (Continuation Sheet), NavFac Form 9-11200/3B.



DAILY FUEL ISSUE REPORT

TYPE FUEL (✓)		PUMP IDENTIFICATION	METER OPEN	METER CLOSED	PUMP OPERATOR
●	●				
●	●				
●	●				
●	●				

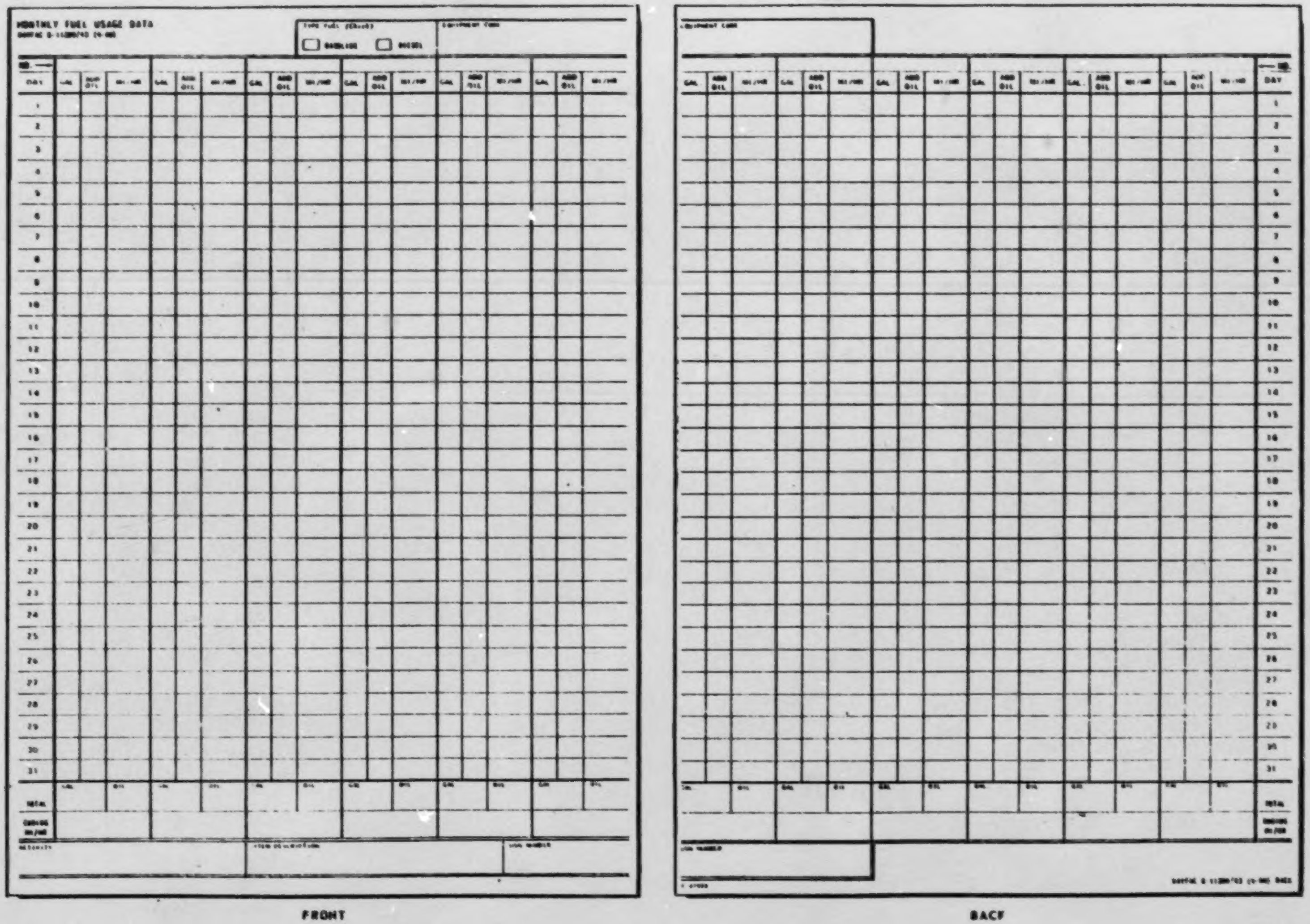
→ SUPPLY COPY

→ DISPATCHER COPY

NAVFAC CODE OR DESCRIPTION	USN NUMBER	MILES OR HOURS	GAL FUEL	QT OIL

2.401

Figure 15-6.—Daily Fuel Issue Report, NavFac Form 6-11200/42.



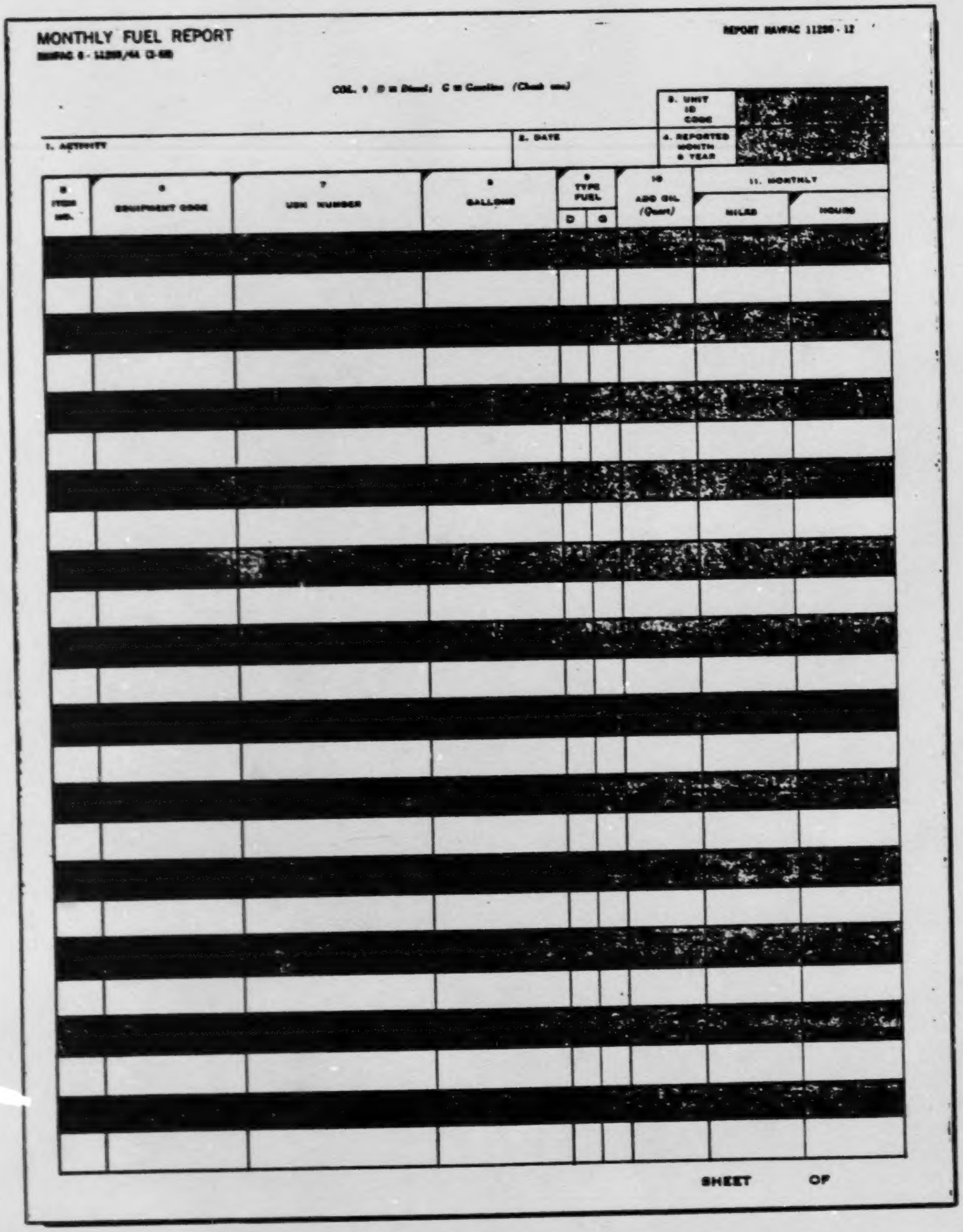
MONTHLY FUEL USAGE DATA

FRONT

BACK

2.402

Figure 15-7.—Monthly Fuel Usage Data, NavFac Form 6-11200/43.



MONTHLY FUEL REPORT
NAVFAC 6 - 11200/44 (3-68)

REPORT NAVFAC 11200 - 12

COL. 9 D = Diesel; G = Gasoline (Check one)

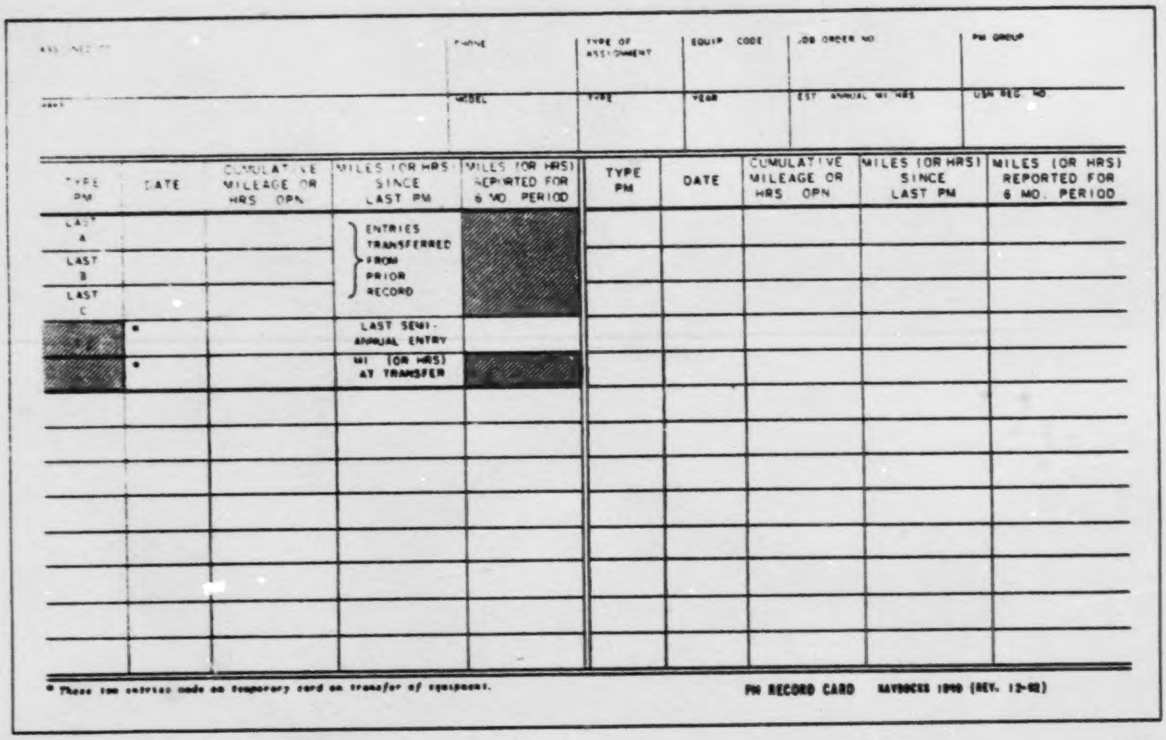
1. ACTIVITY	2. DATE	3. UNIT ID CODE
		4. REPORTED MONTH & YEAR

5 ITEM NO.	6 EQUIPMENT CODE	7 USN NUMBER	8 GALLONS	9 TYPE FUEL D	G	10 ADD OIL (Quart)	11. MONTHLY MILES	HOURS

SHEET OF

2.403

Figure 15-8.—Monthly Fuel Report, NavFac Form 6-11200/44.



ASSIGNED TO	PHONE	TYPE OF ASSIGNMENT	EQUIP CODE	JOB ORDER NO	PM GROUP
MAKE	MODEL	TYPE	YEAR	EST. ANNUAL MI HRS	USN REG. NO

TYPE PM	DATE	CUMULATIVE MILEAGE OR HRS OPN	MILES (OR HRS) SINCE LAST PM	MILES (OR HRS) REPORTED FOR 6 MO. PERIOD	TYPE PM	DATE	CUMULATIVE MILEAGE OR HRS OPN	MILES (OR HRS) SINCE LAST PM	MILES (OR HRS) REPORTED FOR 6 MO. PERIOD
LAST A			ENTRIES TRANSFERRED FROM PRIOR RECORD	▨					
LAST B				▨					
LAST C				▨					
▨	*		LAST SEMI-ANNUAL ENTRY						
▨	*		MI (OR HRS) AT TRANSFER	▨					

* These two entries made on temporary card on transfer of equipment.

PM RECORD CARD NAVDOCKS 1949 (REV. 12-62)

2.10

Figure 15-9.—Preventive Maintenance Record Card, NavDocks 1949 (12-62).

chart furnished with the vehicle. Corrective adjustments and repair actions taken as the result of serviceability inspections must generally be limited to only those items prescribed by the manufacturer and only to the extent necessary to restore the vehicle to an optimum degree of serviceability consistent with achieving the highest degree of cost effectiveness. Where the manufacturer specifies optional adjustments "as required" such adjustments are not made unless a specific malfunction has been detected by the inspector or reported by the operator.

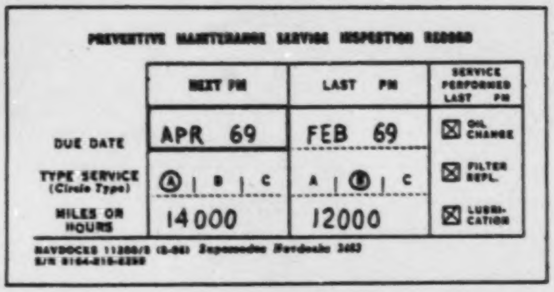
Unscheduled Maintenance Service

Unscheduled maintenance service is the correction of deficiencies reported by the vehicle operator that occur between scheduled safety or other inspections and services as prescribed by the manufacturer. Unscheduled maintenance services will generally be limited to the correction of only those specific items reported as being deficient by the operator and confirmed by qualified inspection personnel. Other unreported deficiencies observed at the time of an unscheduled service and in particular those affecting safety must be corrected prior to releasing the vehicle for service.

MOTOR VEHICLE SAFETY INSPECTION CHECKLIST

Services to be performed each six months or 6,000 miles, whichever occurs first and/or simultaneously with manufacturer's recommended service interval and services, are given in the following checklist:

Brakes	●Test to determine if brakes are functioning properly. ●Check brake pedal free travel as required. ●Remove right front brake drum, inspect for wear or cracking, inspect lining for excessive



PREVENTIVE MAINTENANCE SERVICE INSPECTION RECORD

	NEXT PM	LAST PM	SERVICE PERFORMED LAST PM
DUE DATE	APR 69	FEB 69	☒ OIL CHANGE
TYPE SERVICE (Circle Type)	[✓ A] | B | C	A | [✓ B] | C	☒ FILTER REPL.
MILES OR HOURS	14000	12000	☒ LUBRICATION

81.325

Figure 15-10.—Preventive Maintenance Service Inspection Record, NavDocks 11200/5 (2-66).

	wear, check wheel cylinders for leaks and deterioration (to be performed annually and/or as required to comply with state and local inspection regulations). •Check fluid level and all hydraulic brake lines for leaks. •On air brake systems inspect air brake accessories and all air lines and air tanks for leaks and deterioration; check air brake instrument controls and air valves.
Lights	•Check all lights, signals and reflectors. •Check condition of trailer jumper cable. •Check headlights for proper alignment.
Instruments, Controls, and Warning Devices	•Check all instruments, gages, mirrors, switches, controls, horns and warning devices for proper functioning and damage.
Exhaust System	•Check muffler, exhaust and tailpipes and all connections for leaks.
Steering System	•Check all steering devices and linkage for wear and damage.
Seat Belts	•Check all safety belts for wear and proper mounting.
Fifth Wheel and Trailer	•Check fifth wheel mounting bolts or clamps operation and safety lock. Check trailer king pin for wear or damage.
Tires	•Check all tires for damage and excess wear. •Remove and replace all tires showing 1/16 of an inch or less of tread. Check wheel lug nuts for tightness.
Windshield Wipers, Glass and Defrosters	•Check wipers, glass and defroster for proper operation, wear, damage and deterioration.

The scheduled inspection and service program described pertains to all activities, according to NAVDOCKS P-300. Construction Battalions must conform to the most current COMCBLANT and COMCBPAC 11200 series instructions pertaining to automotive preventive maintenance.

The manufacturer's manual may specify that a certain part may need lubrication at intervals other than the specified PM interval. The vehicle may be brought into the shop to have the individual part serviced. The local maintenance facility will have a policy concerning the arrangement for servicing individual parts on the vehicle or equipment. Construction equipment will not be brought into the shop for this service. The field truck discussed in chapter 14 goes to the equipment. However, the operator of the construction equipment often has to oil and grease certain fittings, which require frequent oiling and greasing, while the equipment is in the field. No PM should be performed at this time; only the part which requires servicing should be serviced.

CONSTRUCTION AND ALLIED EQUIPMENT PM SERVICE SCHEDULE

Preventive maintenance scheduling principles for construction and allied equipment are generally the same as for automotive vehicles. Maintenance is scheduled on the basis of actual hours of operation correlated with time intervals rather than on a fixed-time or mileage interval alone. However, irrespective of usage, all equipment is given a mechanical inspection annually.

The "A" type of inspection for construction and allied equipment is governed by the manufacturer's recommended practices, and is usually limited to lubricating, correcting obvious malfunctions, and making minor adjustments. The type "B" inspection for construction and allied equipment is scheduled for every 250 operating hours. The type "C" inspection is to be performed at intervals of 600 hours of operation or yearly-whichever comes first. NavDocks 2009 and 2161 (figs. 15-11 and 15-12) tabulate the services you are to perform.

LUBRICATION

As you may recall from chapter 5, lubrication cleans and cools moving parts of the vehicle, reduces friction between them, and acts as a sealing agent. This section discusses the procedures of lubrication.

Periodic lubrication prolongs the usefulness of a vehicle. Proper lubrication is more than merely placing a grease gun on a fitting and pulling the trigger. It means selecting the correct lubricants and applying them in a sufficient amount, in the proper places, to penetrate vehicle parts thoroughly. The experienced mechanic uses neither too much nor too little lubricants.

Lubrication, then, is a thorough job of oiling and greasing. Your shop will likely carry several Navy approved standard lubricants. Learn their specifications and names. This standardization of lubricants eliminates the variation and confusion in manufacturer's brand names and quality designations, and makes readily available a few standard lubricants.

Familiarize yourself with the PM Maintenance Service and Inspection Guides (figs. 15-11, and 15-12) and the lubrication chart of the vehicle with which you are working. The manufacturer of each vehicle has prepared a lubrication chart similar to the one shown in figure 15-13. These charts show what to lubricate, and where.

Of course, you must learn to use grease guns properly, as well as other dispensers of oils and grease.

Remember that grease on the outside of a fitting does not lubricate, and oil or grease in puddles or gobs around the grease rack can cause serious injury. So look for and remove spilled oil or grease that drops from chassis parts. Better yet, while lubricating a piece of equipment, remove all excessive grease from the fittings and wipe up lubricants that fall to the floor.

DISPENSING LUBRICANTS

Grease guns and dispensers operate either by hand or are air operated. You have probably used the hand-operated MUZZLE-LOADER type. The muzzle-loader can be taken apart to load it with grease. This type of grease gun, for the most part, is used only in places hard to reach with a pressure gun, or in lubricating water pumps and other accessories requiring a special lubricant. Lubricants used for most chassis parts, however, are forced through the fittings by guns operated by air pressure.

Crankcase oil is generally dispensed with measured containers or with a hand or air operated pumping system. Hand or air operated systems normally have meters that register the amount of oil dispensed. Gear box lubricants are generally dispensed by some type of hand or air operated pumping system. Be sure you use the right lubricant dispensers. To prevent mistakes, each dispenser is marked to show the grade and type of lubricant it contains.

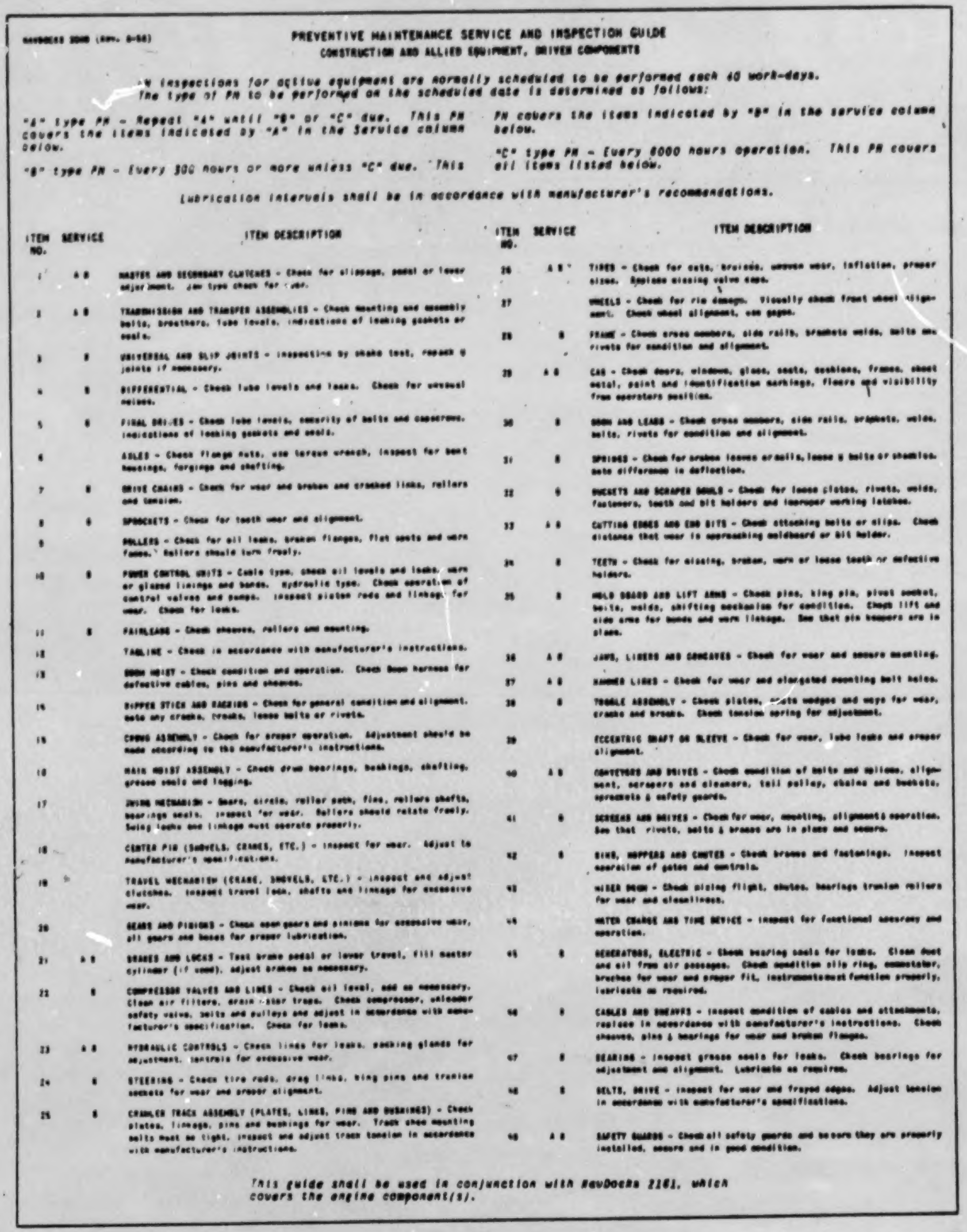
Before using the lubrication gun, all fittings which are to be lubricated MUST be properly cleaned to avoid forcing dirt into the bearing.

The proper technique for using the lubrication gun is essential. Improper use of the gun can damage the hydraulic coupler jaws and can also damage the fitting. Damaged coupler jaws will prevent the proper seal with fittings. To prevent damage, press the coupler straight onto the CLEAN fitting and squeeze the trigger slowly and smoothly.

When using high pressure guns, take-care so that grease seals will not be damaged. To remove the gun, move it up or down or sideways in an arc. Do not pull the gun straight back from the fitting because this will damage the coupler jaws.

CAUTION: Care must be exercised when using a high pressure lube gun on certain lube points. Excessive pressure can damage or "blow off" the grease seals and or dust caps.

After a vehicle is lubricated, clean and fill the grease guns. Then check them to see if they are working properly. Next see that they and other lubricating equipment are stowed in their proper places. Take an inventory of your tools to be sure they are not carried away on the vehicle frame or running board.



NAVDOCKS 2009 (REV. 8-58)

PREVENTIVE MAINTENANCE SERVICE AND INSPECTION GUIDE
CONSTRUCTION AND ALLIED EQUIPMENT, DRIVEN COMPONENTS

PM inspections for active equipment are normally scheduled to be performed each 40 work-days. The type of PM to be performed on the scheduled date is determined as follows:

"A" type PM - Repeat "A" until "B" or "C" due. This PM covers the items indicated by "A" in the Service column below.

"B" type PM - Every 300 hours or more unless "C" due. This PM covers the items indicated by "B" in the service column below.

"C" type PM - Every 8000 hours operation. This PM covers all items listed below.

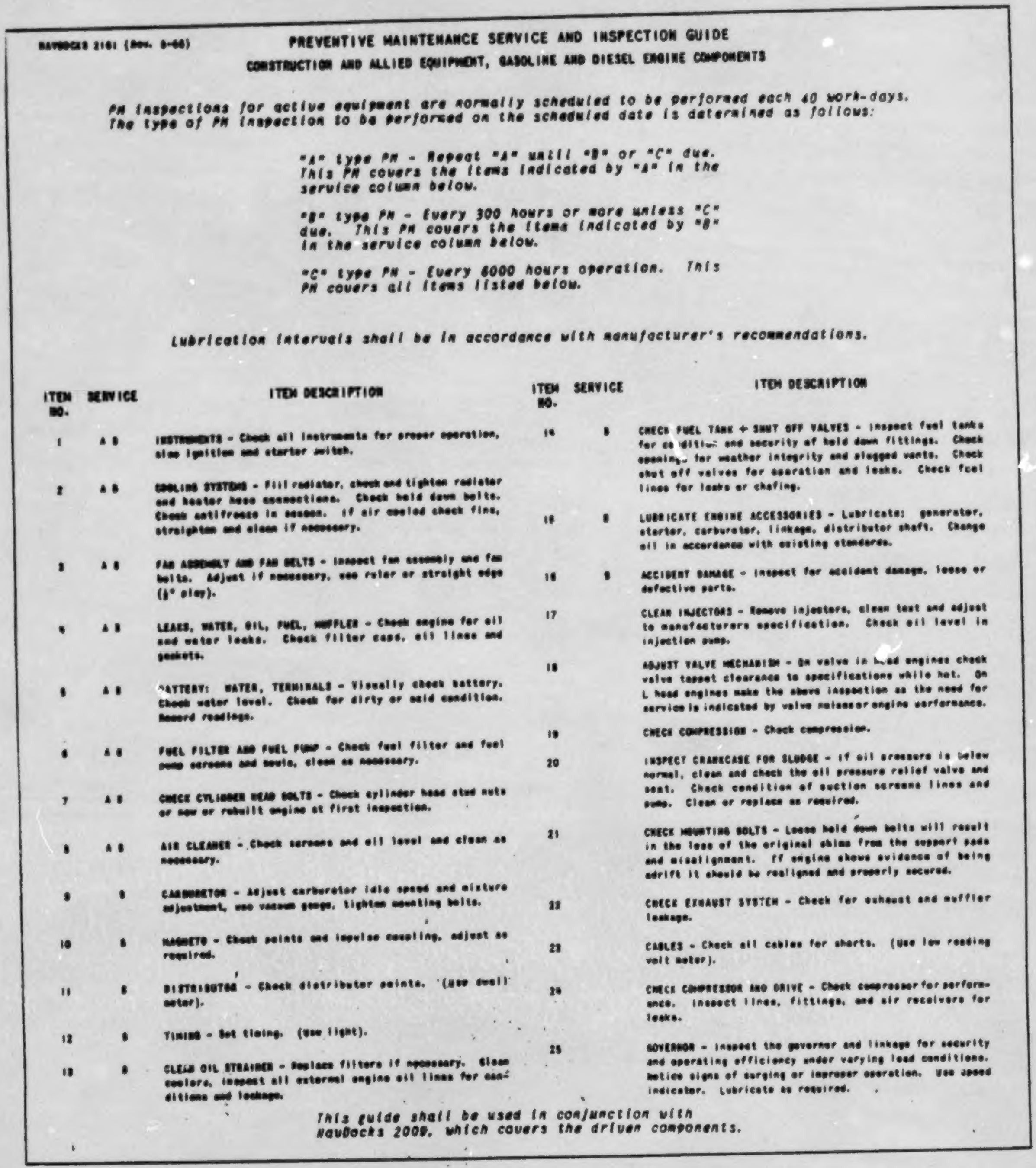
Lubrication intervals shall be in accordance with manufacturer's recommendations.

ITEM NO.	SERVICE	ITEM DESCRIPTION
1	A B	MASTER AND SECONDARY CLUTCHES - Check for slippage, pedal or lever adjustment. Jaw type check for wear.
2	A B	TRANSMISSION AND TRANSFER ASSEMBLIES - Check mounting and assembly bolts, breathers, lube levels, indications of leaking gaskets or seals.
3	B	UNIVERSAL AND SLIP JOINTS - Inspection by shake test, repack U joints if necessary.
4	B	DIFFERENTIAL - Check lube levels and leaks. Check for unusual noises.
5	B	FINAL DRIVES - Check lube levels, security of bolts and capscrews. Indications of leaking gaskets and seals.
6		AXLES - Check flange nuts, use torque wrench, inspect for bent housings, forgings and shafting.
7	B	DRIVE CHAINS - Check for wear and broken and cracked links, rollers and tension.
8	B	SPROCKETS - Check for tooth wear and alignment.
9		ROLLERS - Check for oil leaks, broken flanges, flat spots and worn faces. Rollers should turn freely.
10	B	POWER CONTROL UNITS - Cable type, check oil levels and leaks, worn or glazed linings and bands. Hydraulic type. Check operation of control valves and pumps. Inspect piston rods and linkage for wear. Check for leaks.
11	B	FAIRLEADS - Check sheaves, rollers and mounting.
12		TAGLINE - Check in accordance with manufacturer's instructions.
13		BOOM HOIST - Check condition and operation. Check boom harness for defective cables, pins and sheaves.
14		DIPPER STICK AND RACKING - Check for general condition and alignment. Note any cracks, breaks, loose bolts or rivets.
15		CROWD ASSEMBLY - Check for proper operation. Adjustment should be made according to the manufacturer's instructions.
16		MAIN HOIST ASSEMBLY - Check drum bearings, bushings, shafting, grease seals and lagging.
17		SWING MECHANISM - Gears, circle, roller path, fins, rollers shafts, bearings seals. Inspect for wear. Rollers should rotate freely. Swing locks and linkage must operate properly.
18		CENTER PIN (SHOVELS, CRANES, ETC.) - Inspect for wear. Adjust to manufacturer's specifications.
19		TRAVEL MECHANISM (CRANE, SHOVELS, ETC.) - Inspect and adjust clutches. Inspect travel lock, shafts and linkage for excessive wear.
20		GEARS AND PINIONS - Check open gears and pinions for excessive wear, all gears and boxes for proper lubrication.
21	A B	BRAKES AND LOCKS - Test brake pedal or lever travel, fill master cylinder (if used), adjust brakes as necessary.
22	B	COMPRESSOR VALVES AND LINES - Check oil level, add as necessary. Clean air filters, drain water traps. Check compressor, unloader safety valve, belts and pulleys and adjust in accordance with manufacturer's specification. Check for leaks.
23	A B	HYDRAULIC CONTROLS - Check lines for leaks, packing glands for adjustment, controls for excessive wear.
24	B	STEERING - Check tire rods, drag links, king pins and trunion sockets for wear and proper alignment.
25	B	CRAWLER TRACK ASSEMBLY (PLATES, LINKS, PINS AND BUSHINGS) - Check plates, linkage, pins and bushings for wear. Track shoe mounting bolts must be tight. Inspect and adjust track tension in accordance with manufacturer's instructions.
26	A B	TIRES - Check for cuts, bruises, uneven wear, inflation, proper sizes. Replace missing valve caps.
27		WHEELS - Check for rim damage. Visually check front wheel alignment. Check wheel alignment, use gages.
28	B	FRAME - Check cross members, side rails, brackets welds, bolts and rivets for condition and alignment.
29	A B	CAB - Check doors, windows, glass, seats, cushions, frames, sheet metal, paint and identification markings, floors and visibility from operators position.
30	B	BOOM AND LEADS - Check cross members, side rails, brackets, welds, bolts, rivets for condition and alignment.
31	B	SPRINGS - Check for broken leaves or coils, loose U bolts or shackles. Note difference in deflection.
32	B	BUCKETS AND SCRAPER BOWLS - Check for loose plates, rivets, welds, fasteners, teeth and bit holders and improper working latches.
33	A B	CUTTING EDGES AND END BITS - Check attaching bolts or clips. Check distance that wear is approaching moldboard or bit holder.
34	B	TEETH - Check for missing, broken, worn or loose teeth or defective holders.
35	B	MOLD BOARD AND LIFT ARMS - Check pins, king pin, pivot socket, bolts, welds, shifting mechanism for condition. Check lift and side arms for bends and worn linkage. See that pin keepers are in place.
36	A B	JAWS, LINERS AND CONCAVES - Check for wear and secure mounting.
37	A B	HAMMER LINKS - Check for wear and elongated mounting bolt holes.
38	B	TOGGLE ASSEMBLY - Check plates, seats wedges and ways for wear, cracks and breaks. Check tension spring for adjustment.
39		ECCENTRIC SHAFT OR SLEEVE - Check for wear, lube leaks and proper alignment.
40	A B	CONVEYORS AND DRIVES - Check condition of belts and rollers, alignment, scrapers and cleaners, tail pulley, chains and buckets, sprockets & safety guards.
41	B	SCREENS AND DRIVES - Check for wear, mounting, alignment & operation. See that rivets, bolts & braces are in place and secure.
42	B	BINS, HOPPERS AND CHUTES - Check braces and fastenings. Inspect operation of gates and controls.
43		MIXER DRUM - Check mixing flight, chutes, bearings trunion rollers for wear and cleanliness.
44		WATER CHARGE AND TIME DEVICE - Inspect for functional accuracy and operation.
45	B	GENERATORS, ELECTRIC - Check bearing seals for leaks. Clean dust and oil from air passages. Check condition slip ring, commutator, brushes for wear and proper fit, instruments must function properly, lubricate as required.
46	B	CABLES AND SHEAVES - Inspect condition of cables and attachments, replace in accordance with manufacturer's instructions. Check sheaves, pins & bearings for wear and broken flanges.
47	B	BEARING - Inspect grease seals for leaks. Check bearings for adjustment and alignment. Lubricate as required.
48	B	BELTS, DRIVE - Inspect for wear and frayed edges. Adjust tension in accordance with manufacturer's specifications.
49	A B	SAFETY GUARDS - Check all safety guards and be sure they are properly installed, secure and in good condition.

This guide shall be used in conjunction with NavDocks 2161, which covers the engine component(s).

2.13

Figure 15-11.—Preventive Maintenance Service and Inspection Guide, Construction and Allied Equipment, NavDocks 2009.



NAVDOCKS 2161 (Rev. 6-60)

PREVENTIVE MAINTENANCE SERVICE AND INSPECTION GUIDE

CONSTRUCTION AND ALLIED EQUIPMENT, GASOLINE AND DIESEL ENGINE COMPONENTS

PM inspections for active equipment are normally scheduled to be performed each 40 work-days. The type of PM inspection to be performed on the scheduled date is determined as follows:

"A" type PM - Repeat "A" until "B" or "C" due. This PM covers the items indicated by "A" in the service column below.

"B" type PM - Every 300 hours or more unless "C" due. This PM covers the items indicated by "B" in the service column below.

"C" type PM - Every 6000 hours operation. This PM covers all items listed below.

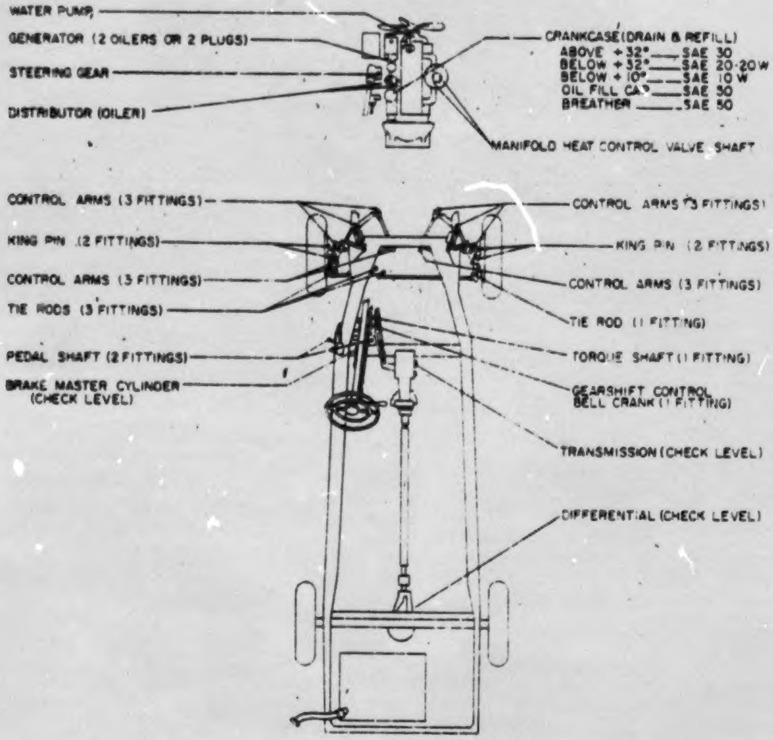
Lubrication intervals shall be in accordance with manufacturer's recommendations.

ITEM NO.	SERVICE	ITEM DESCRIPTION
1	A B	INSTRUMENTS - Check all instruments for proper operation, also ignition and starter switch.
2	A B	COOLING SYSTEMS - Fill radiator, check and tighten radiator and heater hose connections. Check hold down bolts. Check antifreeze in season. If air cooled check fins, straighten and clean if necessary.
3	A B	FAN ASSEMBLY AND FAN BELTS - Inspect fan assembly and fan belts. Adjust if necessary, use ruler or straight edge (½" play).
4	A B	LEAKS, WATER, OIL, FUEL, MUFFLER - Check engine for oil and water leaks. Check filter caps, oil lines and gaskets.
5	A B	BATTERY: WATER, TERMINALS - Visually check battery. Check water level. Check for dirty or acid condition. Record readings.
6	A B	FUEL FILTER AND FUEL PUMP - Check fuel filter and fuel pump screens and bowls, clean as necessary.
7	A B	CHECK CYLINDER HEAD BOLTS - Check cylinder head stud nuts or new or rebuilt engine at first inspection.
8	A B	AIR CLEANER - Check screens and oil level and clean as necessary.
9	B	CARBURETOR - Adjust carburetor idle speed and mixture adjustment, use vacuum gauge, tighten mounting bolts.
10	B	MAGNETO - Check points and impulse coupling, adjust as required.
11	B	DISTRIBUTOR - Check distributor points. (Use dwell meter).
12	B	TIMING - Set timing. (Use light).
13	B	CLEAN OIL STRAINER - Replace filters if necessary. Clean coolers. Inspect all external engine oil lines for conditions and leakage.
14	B	CHECK FUEL TANK + SHUT OFF VALVES - Inspect fuel tanks for condition and security of hold down fittings. Check openings for weather integrity and plugged vents. Check shut off valves for operation and leaks. Check fuel lines for leaks or chafing.
15	B	LUBRICATE ENGINE ACCESSORIES - Lubricate: generator, starter, carburetor, linkage, distributor shaft. Change oil in accordance with existing standards.
16	B	ACCIDENT DAMAGE - Inspect for accident damage, loose or defective parts.
17		CLEAN INJECTORS - Remove injectors, clean test and adjust to manufacturers specification. Check oil level in injection pump.
18		ADJUST VALVE MECHANISM - On valve in head engines check valve tappet clearance to specifications while hot. On L head engines make the above inspection as the need for service is indicated by valve noises or engine performance.
19		CHECK COMPRESSION - Check compression.
20		INSPECT CRANKCASE FOR SLUDGE - If oil pressure is below normal, clean and check the oil pressure relief valve and seat. Check condition of suction screens lines and pump. Clean or replace as required.
21		CHECK MOUNTING BOLTS - Loose hold down bolts will result in the loss of the original shims from the support pads and misalignment. If engine shows evidence of being adrift it should be realigned and properly secured.
22		CHECK EXHAUST SYSTEM - Check for exhaust and muffler leakage.
23		CABLES - Check all cables for shorts. (Use low reading volt meter).
24		CHECK COMPRESSOR AND DRIVE - Check compressor for performance. Inspect lines, fittings, and air receivers for leaks.
25		GOVERNOR - Inspect the governor and linkage for security and operating efficiency under varying load conditions. Notice signs of surging or improper operation. Use speed indicator. Lubricate as required.

This guide shall be used in conjunction with NavDocks 2009, which covers the driven components.

2.14

Figure 15-12.—Preventive Maintenance Service and Inspection Guide, Construction and Allied Equipment, Gasoline and Diesel Engine Components, NavDocks 2161.


WATER PUMP
GENERATOR (2 OILERS OR 2 PLUGS)
STEERING GEAR
DISTRIBUTOR (OILER)
CRANKCASE (DRAIN & REFILL)
ABOVE + 32° — SAE 30
BELOW + 32° — SAE 20-20W
BELOW + 10° — SAE 10 W
OIL FILL CAP — SAE 30
BREATHER — SAE 50
MANIFOLD HEAT CONTROL VALVE SHAFT
CONTROL ARMS (3 FITTINGS)
KING PIN (2 FITTINGS)
CONTROL ARMS (3 FITTINGS)
TIE RODS (3 FITTINGS)
PEDAL SHAFT (2 FITTINGS)
BRAKE MASTER CYLINDER (CHECK LEVEL)
CONTROL ARMS (3 FITTINGS)
KING PIN (2 FITTINGS)
CONTROL ARMS (3 FITTINGS)
TIE ROD (1 FITTING)
TORQUE SHAFT (1 FITTING)
GEARSHIFT CONTROL BELL CRANK (1 FITTING)
TRANSMISSION (CHECK LEVEL)
DIFFERENTIAL (CHECK LEVEL)

29.95

Figure 15-13.—A typical chassis lubrication chart.

Watch for new lubricants and lubrication processes, which are being developed continually. Technical magazines, Navy publications, and your chief are the best sources of information about new developments in lubrication.

CHASSIS LUBRICATION

Most chassis lubrication fittings are located on the front suspension and steering mechanisms. The importance of proper chassis lubrication cannot be overstressed. This lubrication should always be performed in accordance with the manufacturer's lubrication charts.

Some fittings, often referred to as "frozen" fittings, will not readily accept lubricants because the friction surface containing the fitting has dry and dirty working surfaces. Some relative motion in the connection is needed to permit the lubricant to enter the frozen fitting. Rocking the vehicle is the usual method of providing this relative motion in the coupling. In some extreme cases it may be necessary to disassemble the unit being greased in order to properly lubricate it. NEVER pass up a frozen fitting.

BODY LUBRICATION

Cleanliness is the key to body lubrication. Carefully remove any excess lubricant after lubrication since the chassis lubrication points are located where they can easily collect road grit and cause caking. To lubricate the hood, apply a few drops of oil on the fastener-and-release mechanism, coat the fastener pins and hooks, with a light application of dry stick lubricant, and close the hood.

Car doors and trunk lids are lubricated by applying a drop or two of oil to the door latch mechanisms. Also apply a few drops of oil to the hinges and swing the door back and forth or raise and lower the lid to spread the lubricant over the contacting surfaces; wipe off any excess lubricant.

The door striker assembly is lubricated by applying a light coating of dry stick lubricant to all sliding surfaces and a few drops of oil to all bearing surfaces. Apply a drop or two of oil around the edge of the cylinder face and to the outer surface of push-button latches and press the push-buttons several times to distribute the lubricant. Wipe off any excess oil and lubricants.

Never use oil to lubricate locks since it collects dust and lint. Inject graphite directly into the keyhole and work the lock several times to distribute the graphite in the tumbler mechanism.

A dry stick lubricant is best used for sliding weather-stripping surfaces of ashtrays, hinged visors, glove compartments, and other hinged units within the vehicle. Hinged surfaces outside of the vehicle may be lubricated lightly with oil. Always remember that the few minutes it requires to oil these various items will, in most cases, eliminate their failure.

ENGINE AND ENGINE ACCESSORY LUBRICATION

Changing crankcase oil and replacing the oil filter is performed in accordance with the manufacturer's specifications on automotive equipment and at B and C Preventive Maintenance services on construction equipment.

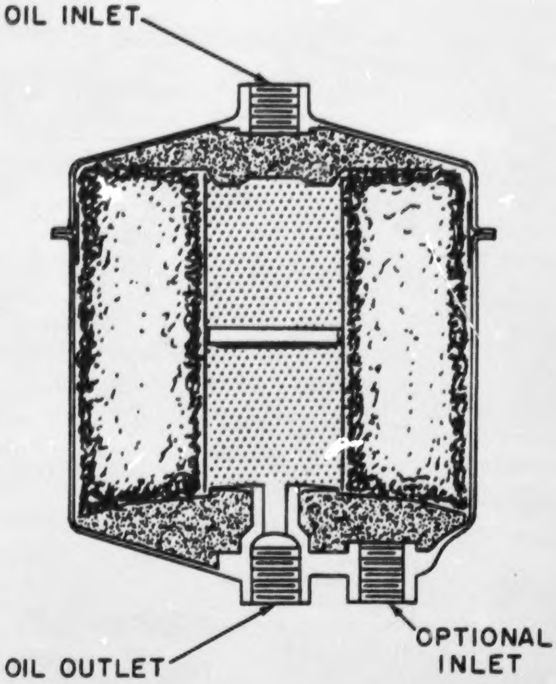
The preferred time to drain the crankcase is immediately after the engine has been run so that the hot oil will drain completely and take along the suspended sludge within the hot oil.

Oil Filter Service

Oil filters, as you may recall from Chapter 5, remove the physical contaminates of the motor oil, but not the chemical. They are effective also in removing metal chips, carbon, dust, and grit from the oil.

The two types of oil filter systems used on automotive engines are the bypass and full-flow types. They bypass type of oil filter is bracket mounted to the cylinder head or manifolds with connecting oil lines to the engine. The oil from the oil pump passes through the oil filter and then to the crankcase in the bypass system. The full-flow type of oil filter is integral with the engine. The oil is directed under pressure through the filter and then to the engine bearings. When the oil is too cold to circulate through the filter in the full-flow system, a bypass valve directs the oil around the filter element.

Bypass systems use three types of filters. They are the throw-away type (fig. 15-14), the screw-on type of throw-away filter (fig. 15-15), and the replaceable element type of filter (fig. 15-16). The full-flow system uses the replaceable element type or the screw-on type of throw-away filter. A replaceable element for a full-flow type filter is shown in figure 15-17.



81.326
Figure 15-14.—Sealed type of throw-away filter.

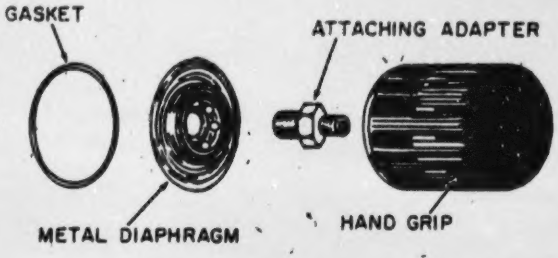


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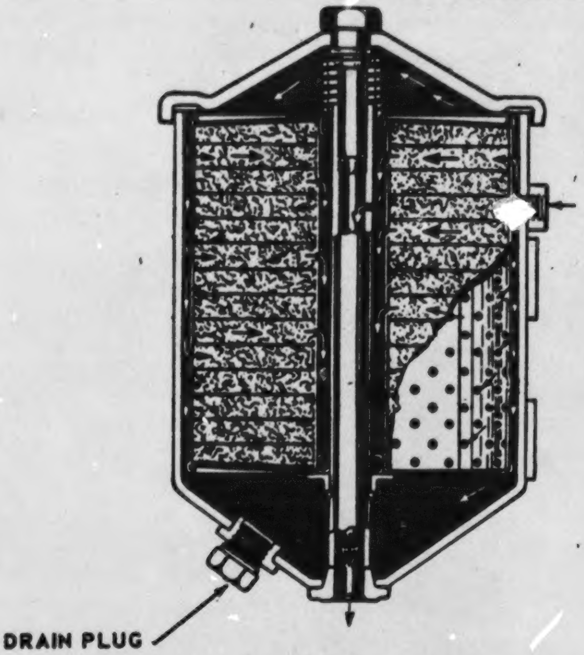
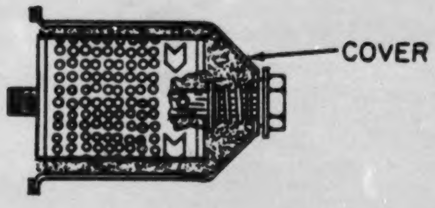
Figure 15-15.—Screw-on type of throw-away filter.



29.27
Figure 15-16.—Replaceable element type filter.

THROW-AWAY OIL FILTER SERVICE.—The throw-away type of oil filter is replaced as a complete unit. You have to disconnect the oil line fittings at the filter. Detach the filter from its bracket and remove the brass fitting from its filter housing. Throw away the filter. Place a bolt or plug into the brass fitting when you are removing or installing it. Brass is maleable (easily bent) and may be crushed by excessive wrench pressure.

SCREW-ON, THROW-AWAY OIL FILTER SERVICE.—The screw-on, throw-away type filter is also replaced as a complete unit. You unscrew the filter from the base by hand and throw the filter away. Wipe the base clean with a cloth, place a small amount of grease or clean lube oil on the new gasket as an added precaution against leakage, and screw a new filter onto the base by hand, tightening at least half a turn after the gasket contacts the base. Start the engine and observe the oil pressure and check for leaks around the oil filter. Stop the engine and add oil to the full level.



81.329
Figure 15-17.—Replaceable element, full-flow type filter.

REPLACEABLE ELEMENT OIL FILTER SERVICE.—To service replaceable element oil filters, you remove the fastening bolt, lift off the cover or remove the filter shell. Remove the gasket and throw it away. When removing the oil filter of the full-flow type, place a pan under the filter to catch the oil. Take out the old element and throw it away. Throw away the gasket from the top and bottom of the center tube if they are present. Place a pan under the filter and remove the drain plug if the filter is used in the bypass system. Clean the inside of the filter shell and cover. Install metal supports and a new bottom tube gasket. Insert a new element and a new top tube gasket. Insert a new cover or housing gasket (make sure that the gasket is completely seated in the recess). Replace the cover or housing and fasten the center bolt securely. Fill the crankcase to the full mark on the dip stick with the proper grade and weight of oil. Start and idle the engine. Check the oil pressure immediately and inspect the filter for oil leaks. Then stop the engine and check the crankcase oil level and add oil to the full mark. The final step in the procedure is to mark the mileage on the sticker so that the element of the oil filter will be replaced at the proper interval.

Air Cleaner Service

Air cleaners filter out the dust and grit particles from the air being taken into the fuel system. The three types of air cleaners used by the Navy are the oil bath, wire gauze, and dry type. Air cleaners should be serviced in accordance with the manufacturers' specifications on automotive equipment and at each B and C inpsection on construction and allied equipment; more often if operating in dusty areas.

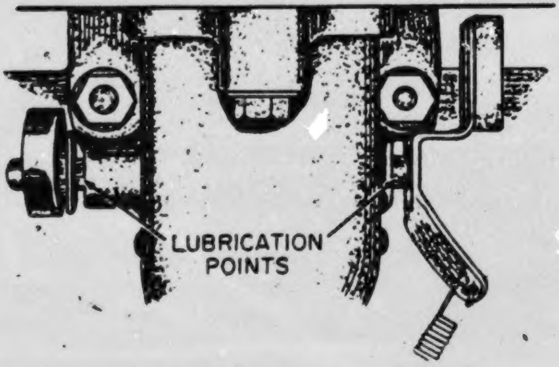
All oil bath cleaners are serviced in a similar manner. You remove and disassemble the unit. On some models, the element and reservoir are all you will need to remove. Wash the filter element in kerosene or other solvent until it is thoroughly clean. Shake excess kerosene from the filter element and dry it in the air (don't use compressed air). Empty the reservoir oil and clean the reservoir. Refill the reservoir to the oil level mark. Replace the filter element, cover, and wing nut. Wipe the entire unit with a clean cloth and carefully place the unit on the carburetor air horn.

The wire gauze type air cleaner has no oil reservoir. The mesh filtering element is washed and soaked with oil at each service period. To service the unit, you remove it from the carburetor air horn. Remove the element and wash it in kerosene or other solvent. Shake the excess kerosene or solvent from the unit and permit it to dry in the air. Oil the wire gauze with motor oil and allow the excess oil to drain. Clean the inside of the filter shell with a clean cloth. Replace the element, cover, and wing nut. Wipe the unit with a clean cloth and replace it on the carburetor air horn.

The dry type carburetor air cleaner uses a paper element. It is serviced by removing the element and shaking and tapping it to remove the dirt.

Manifold Heat Control Valve Service

The manifold heat control valve (fig. 15-18) is another engine accessory which must be lubricated. The manifold heat control valve becomes very hot while operating. A mixture of kerosene, alcohol, or penetrating oil mixed with graphite is used to lubricate the shaft since ordinary lubricant would rapidly burn off. Apply this mixture to both ends while turning the shaft to work the lubricant well into the bearing.



81.330

Figure 15-18.—Typical manifold heat control valve.

Generator Service

Periodic lubrication service is required by most generators. A few generators have sealed bearings which require no lubrication. The generator should be lubricated only at those intervals specified by the manufacturer's lubrication chart.

Distributor Service

The distributor requires service lubrication at three points—the shaft bearing, the centrifugal spark advance mechanism, and the cam. The shaft bearing is lubricated through either an oil cup, grease fitting, or grease cup. Some distributors are equipped with a removable access plug to the shaft bearing reservoir.

The automatic spark centrifugal advance mechanism may be lubricated through a small, round felt wick located at the top of the distributor shaft. Apply two or three drops of motor oil ot the felt wick. With your finger tip, apply a light film of high temperature type grease to the cam. CAUTION: Excess lubricant on the cam may be thrown over to the points and cause ignition failure.

Radiator Fan Service

Most radiator fans are mounted on the water pump shaft and do not require separate lubrication. (Most water pump shaft bearings are factory lubricated and require no lubrication.) However, some radiator fans are equipped with oil reservoirs. You service these by turning the fan until the screw plug on the fan hub is at top center, filling the reservoir, turning the fan until the plug hole is at the bottom (holding a cloth under the drain to prevent oil from dripping onto the fan belt), turning the fan until plug is at top center, and replacing the screw plug. The correct amount of oil will automatically be retained in the fan hub as the excess drains.

RUNNING GEAR LUBRICATION

The running gear is made up of the mechanisms by which the vehicle is controlled and the units on which the vehicle moves. The steering gear, brake system, shock absorbers, and wheel bearings are part of the running gear system.

Steering Gear Service

The gear housing lubricant level should be checked at every chassis lubrication. You should clean around the fill plug on top of the steering gear housing before removing the fill plug. Do not disturb the adjusting screw locknut adjacent to the fill plug. Check the oil level and add lubricant, if necessary, to bring the oil level to the bottom of the fill plug hole. You then replace the fill plug.

Three points require lubrication in power steering systems. The gear housing is serviced on the linkage type of power steering. As you may recall, the linkage type of power steering system has the power cylinder, and control valve connected to the steering linkage and the steering gear of conventional design. Additional lubrication fittings under the car may be found on the power cylinder or the power cylinder attachment points in the linkage type. The fluid reservoir is serviced at each chassis lubrication by cleaning the area, removing the dip stick or reservoir cover, checking the oil level, and replacing the dip stick or cover after adding oil if necessary. Power systems can become inoperative due to dirt in the system, so use care to prevent dirt from entering the reservoir during service operations.

Brake Service

The hydraulic brake master cylinder fluid level should be checked at every chassis lubrication. The fluid level must be visually checked at the reservoir. Pumping the brake pedal does not constitute a complete check. Cleanliness is imperative when servicing the master cylinder. You service the master cylinder by cleaning the area around the fill plug, removing the fill plug, checking the fluid level and refilling the master cylinder reservoir to within half an inch below the fill hole, and replacing the gasket and fill plug. Always use the hydraulic fluid recommended by the manufacturer's lubrication chart. The use of inferior brake fluid or one which contains mineral oil will result in deterioration of the rubber seal, making it necessary to completely overhaul the brake system and flush all brake lines.

Shock Absorber Service

Shock absorbers depend on fluid and valve action for proper control. There are two types of shock absorbers: direct-acting and lever-acting. The direct-acting shock absorber cannot be refilled. It must be replaced if it becomes defective. Shock absorbers should be replaced in sets, front or rear, to maintain body stability. The lever-acting shock absorbers are refilled without being removed from the vehicle. All of the lever-acting shock absorbers are serviced in the same general way. You should clean around the fill plug, loosen the fill plug, and blow away the remaining dust before removing the plug, and blow away the remaining dust before removing the plug. Then fill the shock absorber to hole level with a flexible-spout oiler. If the fill hole is at the top of the housing, do not fill it to the hole level. Leave about 1/8 inch to permit the fluid to expand at high temperatures without causing damage to the shock absorber seals. To remove air pockets in the fluid, bounce the car slightly or work the shock absorber lever back and forth if it is disconnected from the linkage. Replace the plug by hand and gently tighten the plug with a wrench.

Wheel Bearing Service

Wheel bearings should be serviced every time that the brake drums are removed. It is of vital importance that wheel bearing service be performed with utmost care and cleanliness. Most wheel bearing failures result from dirt and grit being introduced to the bearing during lubrication service.

To disassemble the wheel bearings, you should spread out a clean cloth on which to place the parts as you remove them. Remove the outer and inner hubcaps and jack up the wheel until the tire just clears the floor. Remove the cotter pin from the spindle and discard the pin. Then remove the retaining nut and flat washer. Carefully remove the outer bearing and race with an easy shake of the wheel. Do not allow the bearing to drop to the floor. Remove the wheel and inner bearing race from the spindle (ball bearing type—not roll bearing type). Wipe the lubricant from the spindle, remembering to take care to avoid getting grease on the brake linings. You should then clean the loose dust from the brake assembly and the backing plate with a dry brush or compressed air. Next, remove the grease seal from the drum by tapping it out with a brass drift or wood dowel (fig. 15-19). Remove the inner bearing and wash all of the parts except the seal in kerosene or solvent. Be sure that all of the grease is removed. Wipe the old grease from the drum hub and blow the dust from the inside of the drum hub. After this clean the spindle and the inner hub cap by wiping. Then dry all of the parts thoroughly and examine the bearing surfaces

81.331
Figure 15-19.—Tapping out grease seal and inner bearing.

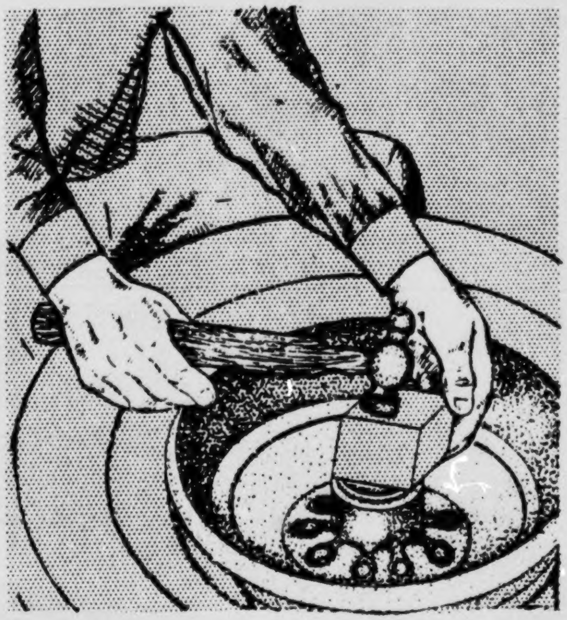
for pits, cracks, chips, or general signs of wear. Replace all defective bearings. You should not spin the bearings when they are dry as they can be easily damaged by this action.

The repacking of the bearings should be done immediately to prevent dust and grit from accumulating on the bearings or in the lubricant. You should use a mechanical bearing packer if it is available. If not, thoroughly pack the lubricant into the bearings with the palm of the hand. You should smear a thin layer of grease inside the wheel hub to prevent rusting; don't pack the inside of the hub with lubricant. The excess lubricant in the hub may possibly get onto the brake linings. Replace the inner bearing and grease seal in the wheel by tapping it into place; use a wood block to protect the seal. See fig. 15-20. You should replace any worn or damaged grease seal with a new one.

When replacing the wheel assembly, you should smear a light coat of wheel bearing grease over the spindle and replace the inner bearing. Next, carefully position the wheel on the spindle, taking care to avoid damage to the spindle. Then place the outer bearing and race into the drum hub and tighten the wheel retaining nut according to manufacturer's torque specifications. If none is specified, tighten until a noticeable drag is felt when the wheel is rotated, and then loosen the retaining nut to the nearest spindle hole and install a new cotter pin. The wheel should be able to rotate freely at this stage. You may lock the new cotter pin if the wheel is able to rotate freely.

If the wheel does not rotate freely when the retaining nut is loosened and the new cotter pin installed, you should determine the cause of the wheel's dragging. Drag may be caused by dragging brakes, out-of-round brake drums, loose backing plates, or defective bearings or races. You may check bearing looseness by rocking the wheel with one hand at the top and the other hand at the bottom of the tire. The looseness of the king pin or ball joints may be checked in the same way, but observation of the movement will indicate the point of looseness.

After locking the cotter pin, and if the inner hubcap contains a static collector, you should clip the leg of the cotter pin to prevent interference. Then wipe the cap, collector and spindle end to ensure good contact for the radio static collector. You may then replace the inner and outer hubcaps.



81.332
Figure 15-20.—Replacing inner bearing and grease seal.

POWER TRAIN LUBRICATION

As you may recall from chapter 10, the power train is a series of power transmitting units which carry the vehicle's driving force from the engine to the wheels. The power train consists of the clutch, transmission, drive shaft, universal joint or joints, differential and rear axles.

Clutch Service

The standard clutch is the single-plate, dry disk type. The pedal and clutch shaft bearings are the only lubrication points on this type of clutch. You should refer to the manufacturer's lubrication chart to determine when to lubricate and which lubricant to use. Most of the late model cars have a clutch release bearing containing enough lubricant to last for the life of the bearing. Some trucks and older cars have a clutch release bearing which requires periodic lubrication. To service the clutch release bearing, you should remove the lower flywheel cover and clean the plug, fitting, or oiler with a clean cloth. Then lubricate sparingly and wipe off any excess lubricant. Then replace the lower flywheel cover.

Transmission Service

The conventional transmission should be checked for lubricant level at each chassis lubrication. Recurrent low lubricant level indicates that there is leakage around the oil seals. If you notice foaming in the oil, you should drain the transmission and refill it with fresh lubricant. Foaming is evidence that water or some other lubricant which will not mix with the recommended lubricant is present. You should drain the transmission immediately after the vehicle has been operated. The lubricant will then be warm and will readily drain and take along the suspended contaminants as it drains. Before you drain the oil, you should clean thoroughly around the drain and fill plugs. The drain and fill plugs should be removed to allow the oil to drain. To refill the transmission with oil, you replace the drain plug and fill the transmission with the proper lubricant until it reaches the bottom of the fill plug hole. Then replace the fill plug.

Universal Joint Service

Universal joints are, as you may recall from chapter 10, devices that are designed to transmit power through the drive shaft while flexing through various angles. The cross and yoke types of universal joints are packed with lubricant at the factory. To repack them, you should mark the bearings, drive shaft, and spline with chalk to ensure their reassembly in the correct position for drive shaft balance. The first step in universal joint service is to bend back the tangs on the locking plates and remove the four bolts holding the rear universal joint to the rear yoke. Next, bind the bearing trunnions onto the cross with wire or tape and lower the rear end of the propeller shaft. Then slide the shaft back off the splined transmission shaft. Mount the drive shaft and the attached universal joint in a bench vise and carefully remove the wire or tape from the two trunnions. Lift off the two trunnions with their washers (being careful not to lose any bearing needles). Next, remove the two bearing retainer rings. The split yoke type universal joints do not have retainer rings; they are disassembled by removing the two cap screws and lifting off each bearing trunnion. After disassembly, position one of the bearing cups over a block of soft metal having a hole in it large enough to permit the bearing cup to pass through. Then drive the opposite bearing with a soft metal punch until the first bearing drops free of the yoke. Turn the assembly over and use the same procedure for removal of the other bearing. Then remove the cross. Use the same procedure for the disassembly of the other universal joints.

Then wash all of the parts carefully. Remove any old grease from the grease holes in the cross. Replace any defective parts and any brittle or worn seals. Then pack the rollers and fill all cavities within the cross with the recommended lubricant. Reassemble the unit in the reverse order of disassembly. Use a vise to press the bearing cups into position.

The ball and trunnion type of universal joint is disassembled for lubrication by removing the nuts, bolts and washers holding both universal joints to the flanges after marking them with chalk to make sure of proper reassembly position. Remove the differential end of the drive shaft by pulling forward enough to clear the flange. Next, remove the transmission end of the drive shaft. Hold an end of the drive shaft in a vise while supporting the other end of the drive shaft. Hold the cover with your free hand to control the pressure of the inner spring and, at the same time, bend up the slips on the metal bend. Then remove the grease cover, gasket, and spring and pull the universal joint body back toward the shaft. Next, remove the bearings from the cross pin and clean the old grease from the cross housing.

Disassemble, wash, and inspect all of the bearing parts. Replace any defective parts. Then lubricate the bearings and reassemble the bearings to the cross pin. After this pull the housing back to its normal position. Loosely fill the housing with the recommended lubricant. Now replace the spring, gasket, and cover. Hold the cover down with one hand to compress the spring while taping the cover clips down. Then replace the shaft assembly by inserting the transmission end first. Make sure that the chalk marks are matched as you replace the belts, washers, and nuts.

The Hotchkiss drive has, as you may recall from chapter 10, a change in drive shaft length as the vehicle travels over uneven surfaces. A spline in the rear universal joint acts as a slip joint to permit the drive shaft's effective length to vary. Some splines are lubricated from the transmission and some are packed with lubricant at the factory and require packing at only recommeded intervals. There are some splines which may be lubricated through a fitting. The manufacturer's lubrication chart should be used to determine the proper lubricant to use and where to apply the lubricant if there is a fitting on the universal joint spline.

Drive Shaft Service

The drive shaft itself is not lubricated, but the drive shaft bearing located in the middle of the drive shaft may require lubrication. Most drive shaft bearings are sealed at the factory and require no lubrication. Those equipped with fittings should be lubricated at regular intervals. You should refer to the manufacturer's lubrication chart to determine the type of lubricant to use and where to apply the lubricant.

Differential Service

The lubrication procedure for the differential varies from model to model; the manufacturer's lubrication chart will indicate the lube points and the amount and type of lubricant to use. Most differentials are filled with lubricant to the bottom of the fill plug. Differentials should be drained after the vehicle has been driven since the warm oil will drain more easily and completely.

MISCELLANEOUS LUBRICATION

There are some vehicle components which do not fall readily into any one category. Electric motors, gearshift levers, and speedometer cables are components which require lubrication service, but which do not fall into any one of the previous categories.

Electric Motor Service

The small electric motors used for automotive accessories are used only intermittently and seldom require lubrication. These electric motors may be equipped with oil impregnated bearings which do not require lubrication. When there is a means to lubricate the motors, you should apply the lubricant sparingly.

Gear Shift Lever Service

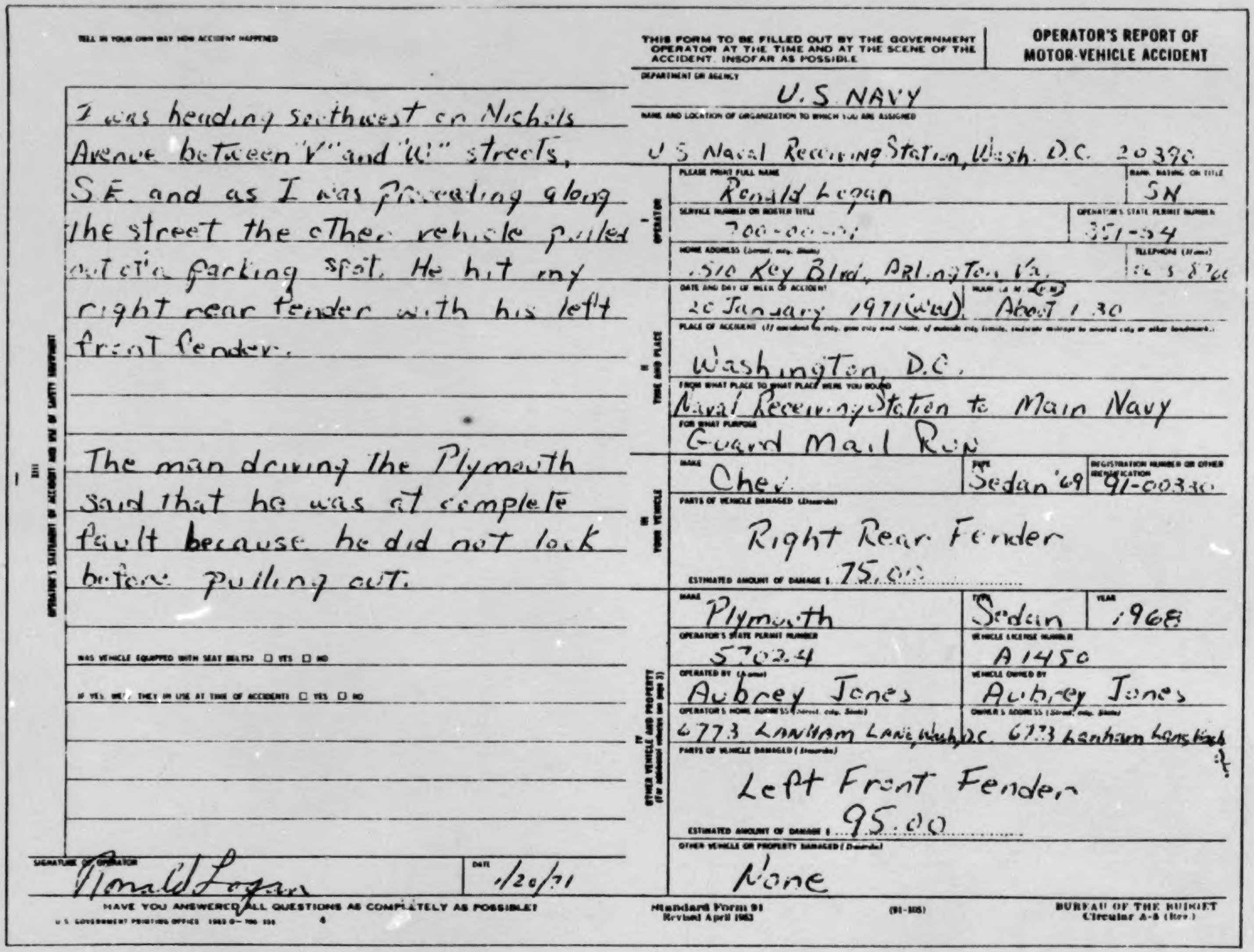
You should occasionally lubricate the friction points of the linkage for gearshift levers mounted on steering columns.

Some vehicles with automatic transmissions require that the automatic transmission linkage be lubricated. You should sparingly lubricate the shift detent lever every 1000 miles for those automatic transmissions which have the shift detent lever.

TROUBLESHOOTING

Before becoming a SEABEE, you may have tinkered with cars as a hobby. The Construction Mechanic does not tinker. He should regard every vehicle as a piece of government equipment which should be maintained in the best possible operating condition. Maintenance also means correcting troubles that could disable and immobilize a vehicle. When you strike for Construction Mechanic First Class, you must be especially good in locating and correcting trouble in gasoline and diesel engines so that you can train lower rated men.

It is not practicable to discuss every phase of troubleshooting in this book, as troubleshooting varies according to make and type of engines involved. Throughout his manual, however, we have discussed certain troubleshooting procedures in connection with operation and maintenance. In general, for specific problems, the manufacturer's manual is your best source of information. Whenever you have an unusual problem on troubleshooting, ask your chief for advice.



TELL IN YOUR OWN WAY HOW ACCIDENT HAPPENED

THIS FORM TO BE FILLED OUT BY THE GOVERNMENT OPERATOR AT THE TIME AND AT THE SCENE OF THE ACCIDENT, INSOFAR AS POSSIBLE

OPERATOR'S REPORT OF MOTOR-VEHICLE ACCIDENT

VIII OPERATOR'S STATEMENT OF ACCIDENT AND USE OF SAFETY EQUIPMENT

I was heading southwest on Nichols Avenue between "V" and "W" streets, S.E. and as I was proceeding along the street the other vehicle pulled out of a parking spot. He hit my right rear fender with his left front fender.

The man driving the Plymouth said that he was at complete fault because he did not look before pulling out.

WAS VEHICLE EQUIPPED WITH SEAT BELTS? ☐ YES ☐ NO

IF YES, WERE THEY IN USE AT TIME OF ACCIDENT? ☐ YES ☐ NO

SIGNATURE OF OPERATOR Ronald Logan

DATE 1/20/71

HAVE YOU ANSWERED ALL QUESTIONS AS COMPLETELY AS POSSIBLE?

U.S. GOVERNMENT PRINTING OFFICE 1963 O—700-336 4

DEPARTMENT OR AGENCY U.S. NAVY

NAME AND LOCATION OF ORGANIZATION TO WHICH YOU ARE ASSIGNED U.S. Naval Receiving Station, Wash. D.C. 20390

I OPERATOR

PLEASE PRINT FULL NAME Ronald Logan

RANK, RATING OR TITLE SN

SERVICE NUMBER OR ROSTER TITLE 700-00-[illegible]

OPERATOR'S STATE PERMIT NUMBER 351-54

HOME ADDRESS (Street, city, State) 510 Key Blvd, Arlington Va.

TELEPHONE (Home) [illegible]5-8760

II TIME AND PLACE

DATE AND DAY OF WEEK OF ACCIDENT 20 January 1971 (Wed)

HOUR (A.M. [✓ P.M.]) About 1:30

PLACE OF ACCIDENT (If accident in city, give city and State; if outside city limits, indicate mileage to nearest city or other landmark.) Washington, D.C.

FROM WHAT PLACE TO WHAT PLACE WERE YOU BOUND Naval Receiving Station to Main Navy

FOR WHAT PURPOSE Guard Mail Run

III YOUR VEHICLE

MAKE Chev.

TYPE Sedan '69

REGISTRATION NUMBER OR OTHER IDENTIFICATION 91-00330

PARTS OF VEHICLE DAMAGED (Describe) Right Rear Fender

ESTIMATED AMOUNT OF DAMAGE $ 75.00

IV OTHER VEHICLE AND PROPERTY (If additional vehicles see page 2)

MAKE Plymouth

TYPE Sedan

YEAR 1968

OPERATOR'S STATE PERMIT NUMBER 57024

VEHICLE LICENSE NUMBER A1450

OPERATED BY (Name) Aubrey Jones

VEHICLE OWNED BY Aubrey Jones

OPERATOR'S HOME ADDRESS (Street, city, State) 6773 Lanham Lane, Wash, D.C.

OWNER'S ADDRESS (Street, city, State) 6773 Lanham Lane, Wash, D.C.

PARTS OF VEHICLE DAMAGED (Describe) Left Front Fender

ESTIMATED AMOUNT OF DAMAGE $ 95.00

OTHER VEHICLE OR PROPERTY DAMAGED (Describe) None

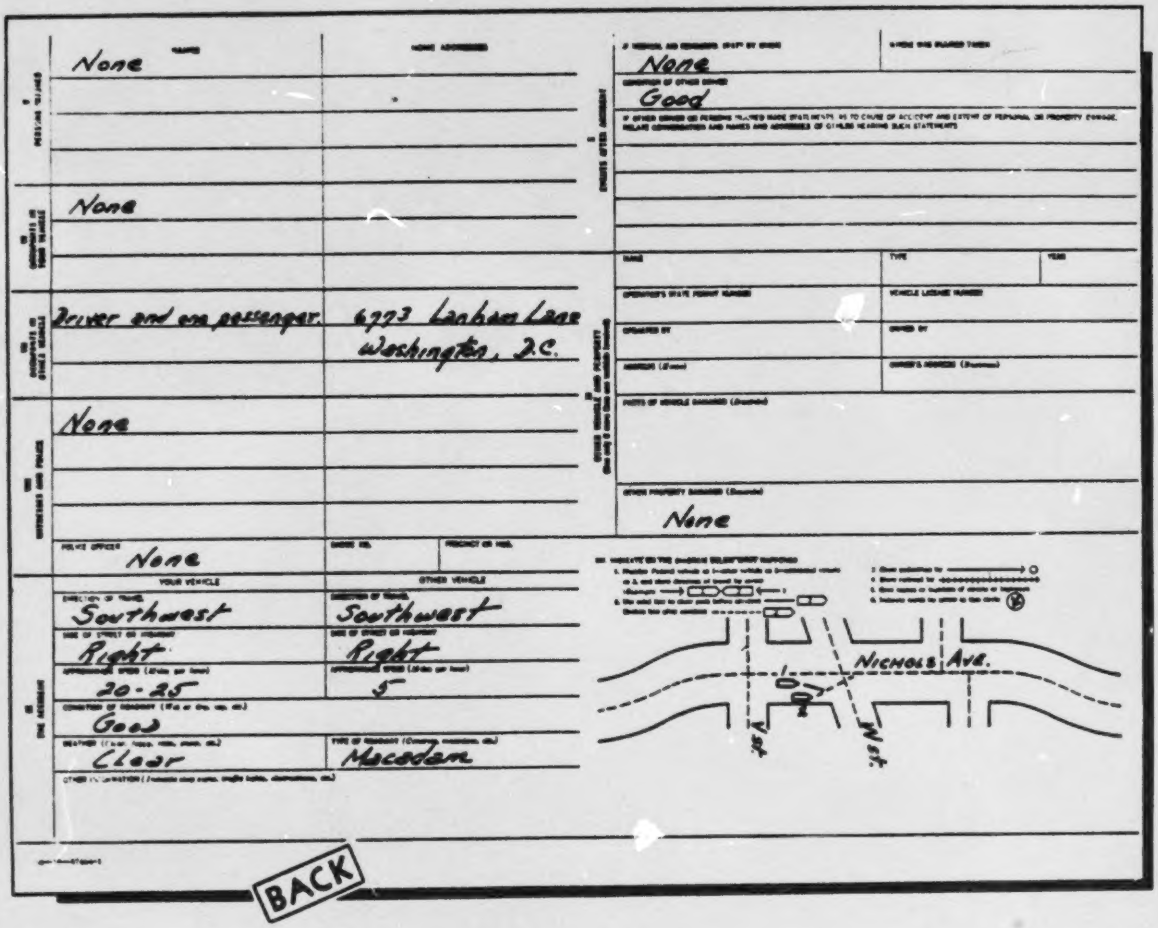
Standard Form 91
Revised April 1963

(91-105)

BUREAU OF THE BUDGET
Circular A-8 (Rev.)

29.52.1

Figure 15-21.—Operator's Report of Motor Vehicle Accident, Standard Form 91 (front).



None

None

Driver and one passenger.

6773 Lanham Lane
Washington, D.C.

None

None

Southwest

Right

20-25

Good

Clear

Southwest

Right

5

Macadam

None

Good

None

Nichols Ave.
V St.
W St.
BACK

29.52.2

Figure 15-22.—Operator's Report of Motor Vehicle Accident, Standard Form 91 (back).

OPERATION OF AUTOMOTIVE EQUIPMENT

As a Construction Mechanic 2 you will be required to "operate automotive equipment... to perform maintenance, repair, and overhaul tasks." Only by operating and driving a vehicle will you be able to check conditions such as engine knocks, chassis rattles, transmission and rear end noises, and be able to ROAD TEST new and overhauled vehicles.

Driving any vehicle, even briefly, requires a Department of Defense (DOD) driving license; a civilian license will not qualify you to drive a Navy vehicle. If you do not already have a DOD license, your chief will instruct you how and where to apply for it and what preparation is necessary to pass the examination required.

You do not want to have occasion to use a standard Form 91, Operator's Report of Motor Vehicle Accident, but you should be familiar with it—just in case. This form must be carried in each vehicle, and if you have an accident, fill it out on the spot or as promptly thereafter as possible. No matter how small the accident, and whether or not there is any apparent injury or property damage, this form must be filled out. It is easily prepared, as you can see figure 15-21 and figure 15-22, so a lengthy explanation is not necessary.

Steelworker 3 & 2

CHAPTER 8

OXYACETYLENE WELDING

Oxyacetylene welding is a gas-welding process wherein coalescence is produced by heating with a gas flame or flames obtained from the combustion of acetylene with oxygen, with or without the application of pressure and with or without the use of filler metal. The two gases are mixed to correct proportions in a torch. The torch can be adjusted to give various types of flames.

A properly made oxyacetylene weld is uniform in appearance, showing a uniform deposit of weld metal. Complete fusion of the side walls is necessary in order to form a good joint. Some of the factors that must be considered in making an oxyacetylene weld are edge preparation, spacing and alignment of the parts, temperature control (before, during, and after the welding process), size of the torch tip, size and type of the filler rod, flame adjustment, and rod and torch manipulation. In some cases, fluxes are required to remove oxide and slag from the molten metal and to protect the puddle from contact with the air.

When sections of plate are to be joined by oxyacetylene welding, the edges of the plate at the joint are melted down uniformly by use of the torch. For welding light sheet metal, filler metal is not usually necessary; the edges of light sheet are flanged at the joint and melted so that they flow together to form one solid piece. In welding heavier sheets and plates, filler metals are required. The edges of the heavier plate are usually beveled to permit penetration to the base of the joint. Both the filler metal and the base metal are melted; as they solidify, they form one continuous piece.

This chapter discusses equipment and materials used in oxyacetylene welding. Information is given on the operation and maintenance of oxyacetylene equipment. Coverage includes techniques of welding and safety precautions relating to oxyacetylene work. A brief discussion also is presented on methylacetylene propadiene (MAPP) gas, which currently is being used for welding, as well as other operations, in the SEABEES.

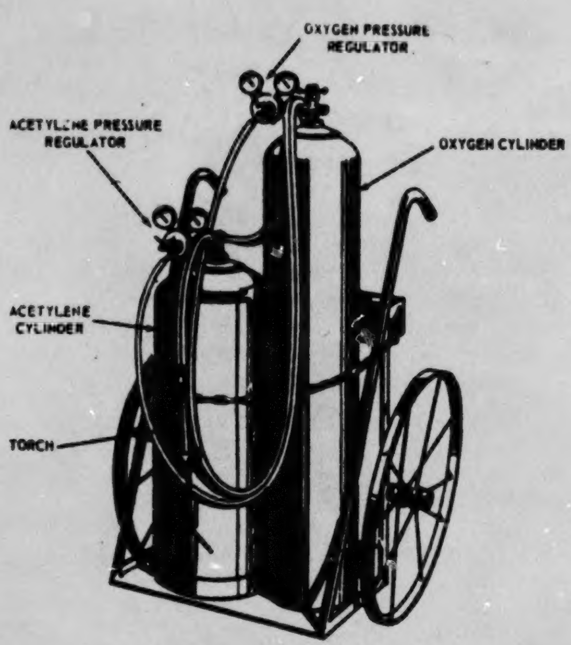
OXYACETYLENE WELDING EQUIPMENT

An oxyacetylene welding outfit, as commonly used, consists of a cylinder of acetylene, a cylinder of oxygen, two regulators, two lengths of hose with fittings, and a welding handle with tips. (See fig. 8-1.) The oxyacetylene outfit also is called a welding rig.

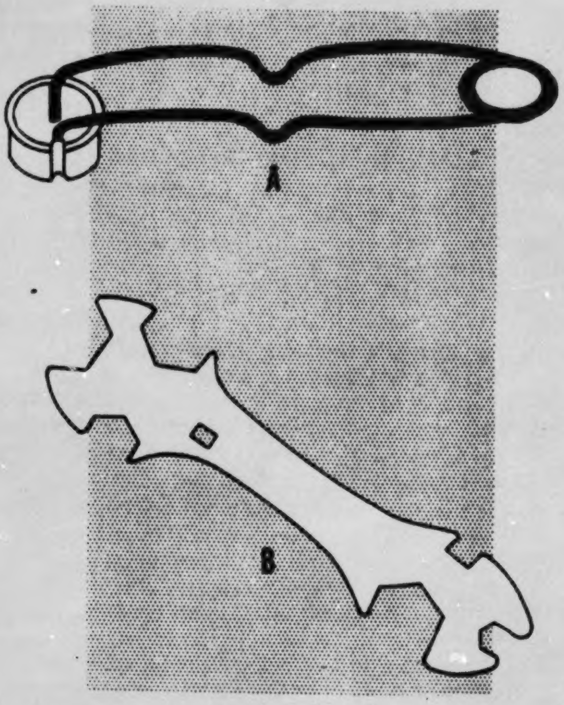
In addition to the basic equipment mentioned above, numerous kinds of auxiliary equipment are used in oxyacetylene welding. A very important item is the spark igniter which is used to light the torch (see view A, fig. 8-2). Another item you will use a lot is an apparatus wrench, the same or similar in design to that shown in view B, figure 8-2. The apparatus wrench is sometimes called a gang wrench because it will fit all the connections on the welding rig. Note that the wrench illustrated has a raised opening in the handle proper which serves as an acetylene tank key. Other common accessories include tip cleaners, cylinder trucks, clamps, and holding jigs. Safety apparel, such as goggles, handshields, gloves, leather aprons, sleeves and leggings, also is essential and should be worn as required for the job at hand. Information on safety apparel is contained in chapter 7 of this text.

Oxyacetylene welding equipment may be stationary or portable. A portable oxyacetylene outfit, such as that shown in figure 8-1, is an advantage where it is necessary that the equipment be moved around from one job to another.

To carry out your welding duties you must be able to set up the welding equipment and make various adjustments required to perform the operation at hand. Thus, it is important that you understand the purpose and function of the basic pieces of equipment that make up the welding outfit. But before discussing the apparatus, let us look at the gases used in oxyacetylene welding; namely, acetylene and oxygen.



11.96
Figure 8-1.—Portable oxyacetylene outfit.



127.15
Figure 8-2.—(A) Spark igniter. (B) Apparatus wrench.

ACETYLENE

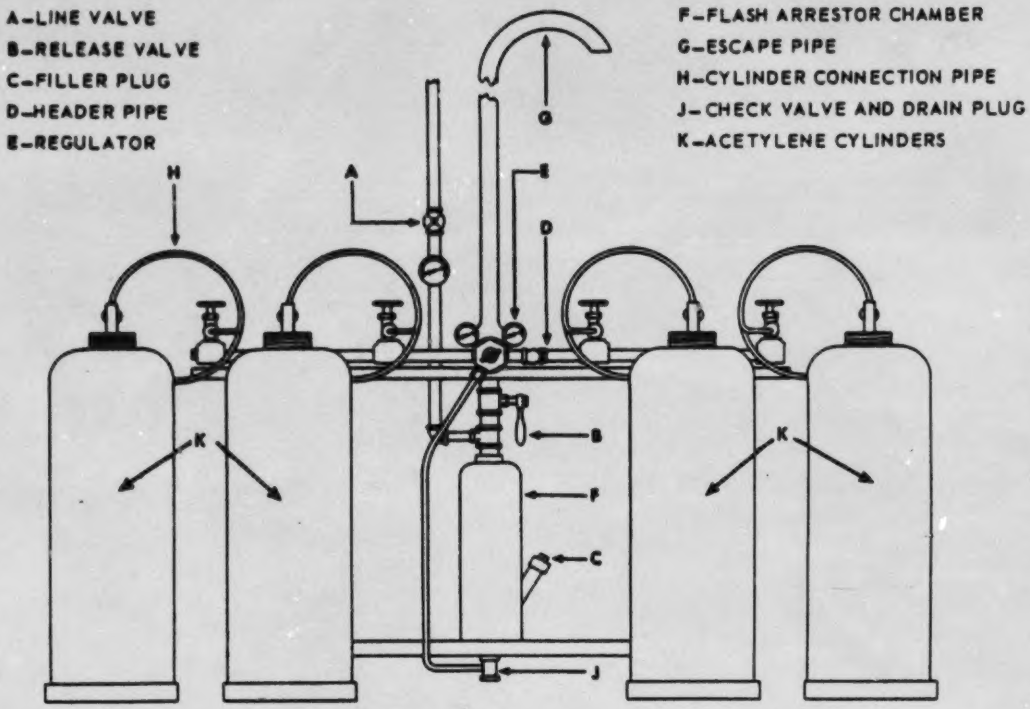
Acetylene is a flammable fuel gas made up of carbon and hydrogen. Its chemical formula is C_2H_2. When burned with oxygen, acetylene produces a very hot flame having a temperature between 5700° and 6300° F. Acetylene is a colorless gas, which has a disagreeable odor that is easily detected, even when the gas is greatly diluted with air. When a portable type welding outfit like that shown in figure 8-1 is used, acetylene is obtained directly from the cylinder. In the case of stationary equipment, like the acetylene cylinder bank illustrated in figure 8-3, the acetylene can be piped to a number of welding stations.

Whether you obtain acetylene from a single cylinder or from a stationary type cylinder bank, acetylene is dissolved in acetone (a liquid) and compressed in a cylinder filled with some porous material such as balsa wood, charcoal, finely shredded asbestos, corn pith, portland cement, or infusorial earth. These porous filler materials are used to decrease the size of the open spaces in the cylinder, and thus reduce the danger of explosion. Pure acetylene, when stored in the free state under a pressure of 29.4 pounds per square inch (psi) becomes self-explosive, and a slight shock is likely to cause it to explode. Dissolved in acetone, however, and stored in cylinders that are filled with porous material, it can be compressed into cylinders at pressures up to 275 psi. An acetylene cylinder is shown in figure 8-4.

To find the amount, in cubic feet, of acetylene in a cylinder, first weigh the full cylinder and deduct the tare (i.e., the weight stamped on the cylinder). Then multiply the difference in pounds by 14-1/2, and the answer is the cubic feet of acetylene in the cylinder. Incidentally, the figure 14-1/2 is used because compressed acetylene is rated under atmospheric pressure and normal temperature as weighing 14-1/2 cubic feet per pound.

Acetylene Generation

While part of your supply of acetylene may be furnished to cylinders, you can generate this



11.97X

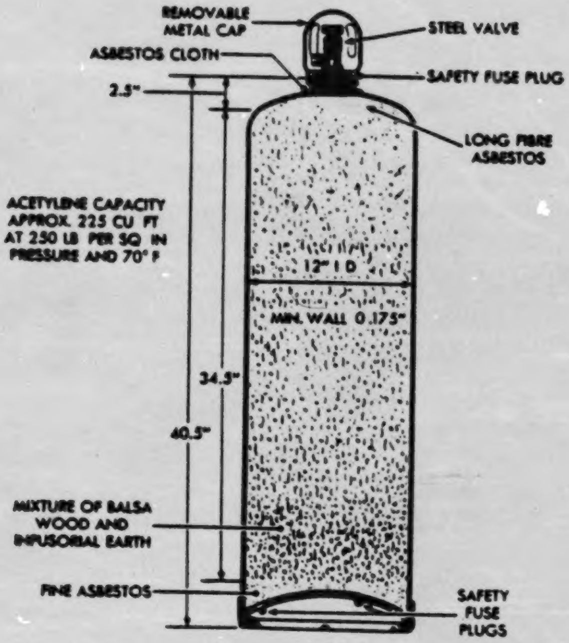
Figure 8-3.—Stationary acetylene cylinder bank.

gas by using a generator made especially for this purpose. There are several industrial processes by which acetylene may be produced. One process of producing acetylene gas is by the action of water on calcium carbide. In this process, acetylene is formed by combining calcium carbide and water in the acetylene generator. We might note that there are three main types of generators—the carbide-to-water, water-to-carbide, and the recession type. The type available for your use, however, will probably be a portable carbide-to-water type of generator. Several sizes of these generators are available. The amount of carbide used at one time may range from 25 to 300 lbs. The gas is generated at pressures from 1 psi to a maximum of 15 psi, depending on the job to be done.

For most oxyacetylene welding, you can use a portable diaphragm feed control generator like that illustrated in figure 8-5. The main parts of this unit are a carbide hopper, water chamber, and flashback arrester. The carbide hopper is made of heatproof glass so you can see how much carbide is in the hopper at any time.

The diaphragm feed control mechanism consists of a rubber diaphragm, a pressure adjustment screw, compression spring, and a locking lever, all located in the top of the hopper. The feed rod is connected to the feed control mechanism by a flexible joint. To start the generator, lift the locking lever to the feed position. This makes the spring press against the diaphragm, which forces the feed rod down, and opens the feed valve so the carbide can drop into the water.

As the gas is generated, it passes up through the carbide feed opening into the hopper. When the pressure of the gas on the diaphragm builds up enough to push the diaphragm upward, it causes the feed rod to rise. When the feed rod rises as far as it can, it closes the carbide feed valve. This action stops the flow of carbide. As soon as the gas pressure on the diaphragm drops, the spring forces the feed rod down, allowing the carbide to drop and begin the generation


REMOVABLE METAL CAP
STEEL VALVE
ASBESTOS CLOTH
SAFETY FUSE PLUG
2.5"
LONG FIBRE ASBESTOS
ACETYLENE CAPACITY APPROX. 225 CU FT AT 250 LB PER SQ IN PRESSURE AND 70° F
12" I D
MIN. WALL 0.175"
34.5"
40.5"
MIXTURE OF BALSA WOOD AND INFUSORIAL EARTH
FINE ASBESTOS
SAFETY FUSE PLUGS

11.98X
Figure 8-4.—Acetylene cylinder.

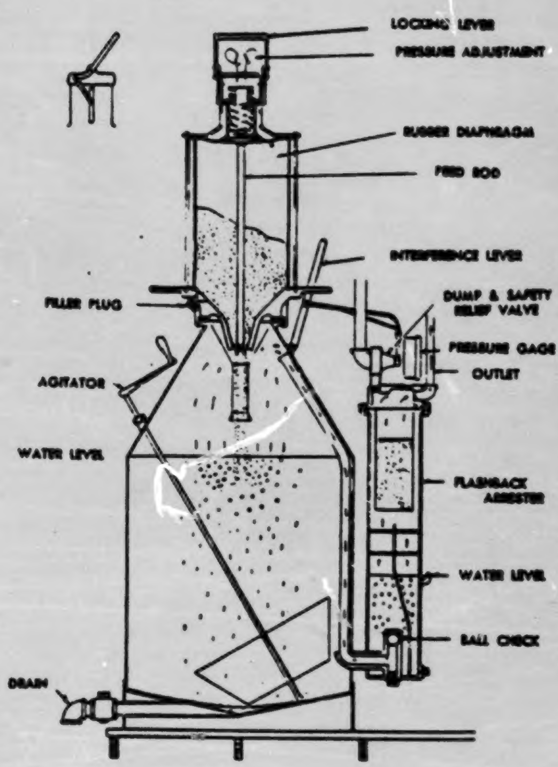
of gas again. This whole chain of action repeats itself as the gas goes up into the carbide hopper. To set the flow of gas at the pressure needed, change the tension on spring by turning the pressure adjustment screw.

Precautions for Acetylene Generation

Under normal pressure and temperature, if acetylene mixes with air, it only needs a spark to blow up. And if acetylene is at a pressure over 30 psi, it doesn't even need air to explode—just a spark will do it. These points were taken into consideration by the National Board of Fire Underwriters, when the organization set up standard rules for the operation and maintenance of all types of acetylene generators. These rules follow, but be sure you also read the manufacturer's instructions for the particular generator you use.

1. A generator must not be used within 10 feet of material that will burn.

2. A generator must always be upright, with well-ventilated free space around it.


LOCKING LEVER
PRESSURE ADJUSTMENT
RUBBER DIAPHRAGM
FEED ROD
INTERFERENCE LEVER
FILLER PLUG
DUMP & SAFETY RELIEF VALVE
PRESSURE GAGE
OUTLET
AGITATOR
WATER LEVEL
FLASHBACK ARRESTER
WATER LEVEL
BALL CHECK
DRAIN

127.160
Figure 8-5.—Portable diaphragm feed control generator.

3. A full generator should not be moved by crane or derrick.

4. To avoid overfilling a generator, water must not be supplied through a continuous connection.

5. Water in a generator must be protected from freezing by steam or hot water.

6. Never let a generator put out more acetylene than the maximum marked on it. The Underwriters' Laboratories specify 1 cubic foot of gas per pound of carbide per hour.

7. If a generator is used inside a building, take it outside before you start charging or cleaning it.

8. When not in use, a generator should not be stored near open lights or fires, UNLESS

you have checked to see that it is entirely empty of carbide and gas.

9. Be sure to check the water seal chamber in the flashback arrester, to see that it has the proper water level.

10. Check all relief valves to see that they work freely and do not leak.

11. Drain connections must not be continuous to sewers, but through open connections into a properly vented outdoor residue pit.

12. If a generator gets hot while operating, stop the feed mechanism and let the generator cool before you look for the trouble.

13. The ratio of carbide to water in making acetylene gas is 1-to-1 (that is, 1 pound of water for each pound of carbide). Use of the correct carbide-to-water mixture in portable acetylene generators is very important since there is the possibility of an explosion if incorrect mixtures or proportions are used.

14. Hot repairs should not be made in a room with other generators—make repairs outside.

15. When charging, repairing, or removing calcium carbide, keep proper water level to avoid explosions in the water space.

16. Piping to carry acetylene may be above or below ground. All piping must be run as directly as possible.

a. Underground piping must be laid below the frost line. When set up, it must be thoroughly blown out with air or nitrogen to remove all dirt.

b. Outdoor piping must be painted to protect it from rust.

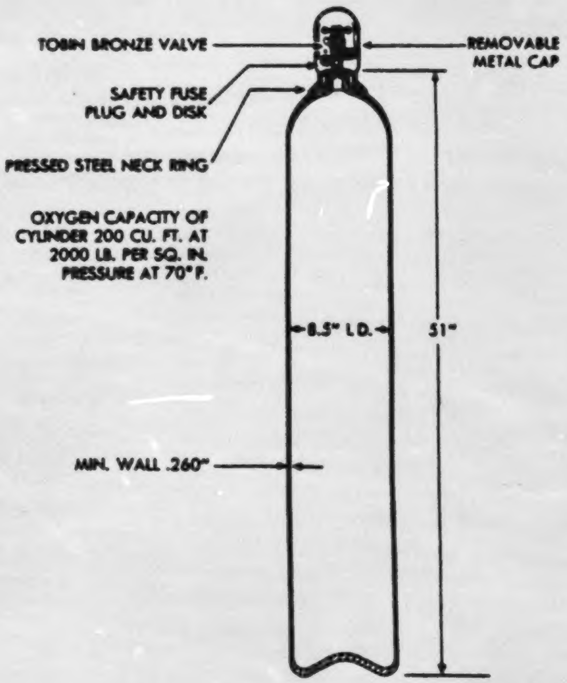
OXYGEN

Oxygen is a colorless, tasteless, and ordorless gas that is slightly heavier than air. It is nonflammable but will support combustion with other elements. In its free state oxygen is one of the most common elements. The atmosphere is made up of approximately 21 parts of oxygen and 78 parts of nitrogen, the remainder being rare gases. Rusting of ferrous metals, discoloration of copper, and the corrosion of aluminum are all due to the action of atmospheric oxygen. This action is known as oxidation.

Oxygen is obtained commercially either by the liquid-air process or by the electrolytic process. In the liquid-air process, the air is compressed and then cooled to a point where the gases become liquid (approximately -375° F). The temperature is then raised to above -321° F, at which point the nitrogen in the air becomes gas again and is removed. When the temperature of the remaining liquid is raised to -297° F, the oxygen forms gas and is taken off. The oxygen is then further purified and compressed into cylinders for use.

The other process by which oxygen is obtained, the electrolytic process, consists of running an electric current through water to which an acid or alkali has been added. The oxygen collects at the positive terminal and is passed off through pipes to a container.

When supplied for use in oxyacetylene welding, oxygen is contained in seamless steel cylinders. A typical oxygen cylinder is illustrated in figure 8-6. Oxygen cylinders are made in several sizes. You will probably find, however, that the size most generally used in welding and cutting


TOBIN BRONZE VALVE
REMOVABLE METAL CAP
SAFETY FUSE PLUG AND DISK
PRESSED STEEL NECK RING
OXYGEN CAPACITY OF CYLINDER 200 CU. FT. AT 2000 LB. PER SQ. IN. PRESSURE AT 70°F.
8.5" I.D.
51"
MIN. WALL .260"

127.16X
Figure 8-6.—Typical oxygen cylinder.

640

is the 220-cubic foot capacity cylinder. It is 9-1/8 inches in diameter and weighs about 145 pounds. This cylinder is charged to a pressure of 2000 psi at a room temperature of 63° F.

You can tell the amount of oxygen in a compressed-gas cylinder by reading the volume scale on the high pressure gage attached to the regulator.

IDENTIFICATION OF CYLINDERS

Color warnings provide an effective means for marking physical hazards, for indicating the location of safety equipment, and for identifying fire and other protective equipment. You will find uniform colors used for marking compressed-gas cylinders, pipelines carrying hazardous materials, and fire protection equipment.

Five classes of material have been selected to represent the general hazards for all dangerous materials, while a sixth class has been reserved for fire protection equipment. A standard color has been chosen to represent each of these classes, as indicated in table 8-1.

Since you will often work with acetylene and oxygen, you must be thoroughly familiar with the colors of the cylinders in which these gases are contained. The acetylene cylinder is yellow, and the oxygen cylinder is green.

In addition to color coding, the exact identification of the material contained in a compressed-gas cylinder must be indicated by a written title, which should appear in two locations

127.159
Table 8-1.—Warning Colors

Class	Standard Color	Class of Material
a	Yellow, No. 13655	FLAMMABLE MATERIALS. All materials known ordinarily as flammables or combustibles. Of the chromatic colors, it has the highest coefficient of reflection under white light and can be recognized under the poorest conditions of illumination.
b	Brown, No. 10080	TOXIC AND POISONOUS MATERIALS. All materials extremely hazardous to life or health under normal conditions as toxics or poisons.
c	Blue, No. 15102	ANESTHETICS AND HARMFUL MATERIALS. All materials productive of anesthetic vapors and all liquid chemicals and compounds hazardous to life and property but not normally productive of dangerous quantities of fumes or vapors.
d	Green, No. 14260	OXIDIZING MATERIALS. All materials which readily furnish oxygen for combustion and fire producers which react explosively or with the evolution of heat in contact with many other materials.
e	Gray, No. 16187	PHYSICALLY DANGEROUS MATERIALS. All materials, not dangerous in themselves, which are asphyxiating in confined areas or which are generally handled in a dangerous physical state of pressure or temperature.
f	Red, No. 11105	FIRE PROTECTION MATERIALS. All materials provided in piping systems or in compressed-gas cylinders exclusively for use in fire protection.

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diametrically opposite and parallel to the longitudinal axis of the cylinder. Cylinders having a background color of yellow, orange, or buff will have the title painted black. Cylinders having a background color of red, brown, black, blue, gray, or green will have the title painted white.

A primary color warning is the color assigned to the class of material into which a material is classified in accordance with its primary hazard from the safety standpoint. These colors appear as main body, top, or band colors on compressed-gas cylinders.

A secondary color warning is the color assigned as a warning of a secondary hazard possessed by a material having a type of hazard distinctly different from that indicated by its primary color warning. These colors also appear main body, top, or band colors on compressed-gas cylinders.

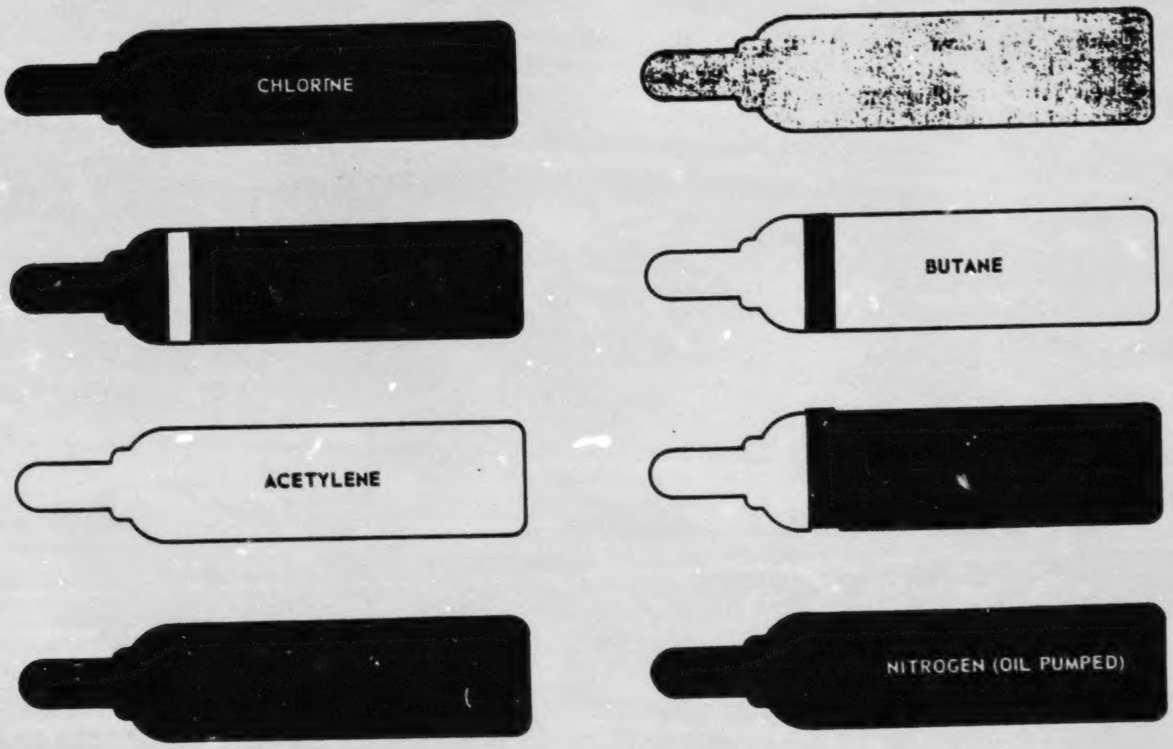
Two decalcomanias, abbreviated "decals," may be applied on the shoulder of each cylinder diametrically opposite at right angles to the titles. They should indicate the name of the gas, precautions for handling, and use. A background color corresponding to the primary color warning of the contents should be used.

Shatterproof cylinders must be stenciled with the phrase "Non-Shat" longitudinally 90° from titles. Letters must be black or white and approximately 1 inch in size.

On cylinders owned by or procured for the Department of Defense, the bottom and the lower portion of the cylinder body opposite the valve end may be used for Service ownership titles.

The appearance on the body, top, or as a band(s) on compressed-gas cylinders of any of the six colors in table 8-1 will provide a warning of danger from the hazard involved in handling the type of material contained in the cylinder.

Figure 8-7 shows cylinders most commonly found in a Construction Battalion or in a Public Works Department where SEABEE personnel will be working. For complete listing of compressed-gas cylinders refer to MIL-STD 101A, "Color Code for Pipelines and for Compressed-Gas



C54.9
Figure 8-7.—Compressed-gas cylinders.

Cylinders," but, in so doing make sure you have a manual with the latest up-to-date changes inserted, as changes may occur in the manual, as prescribed by the Department of Defense, after this writing.

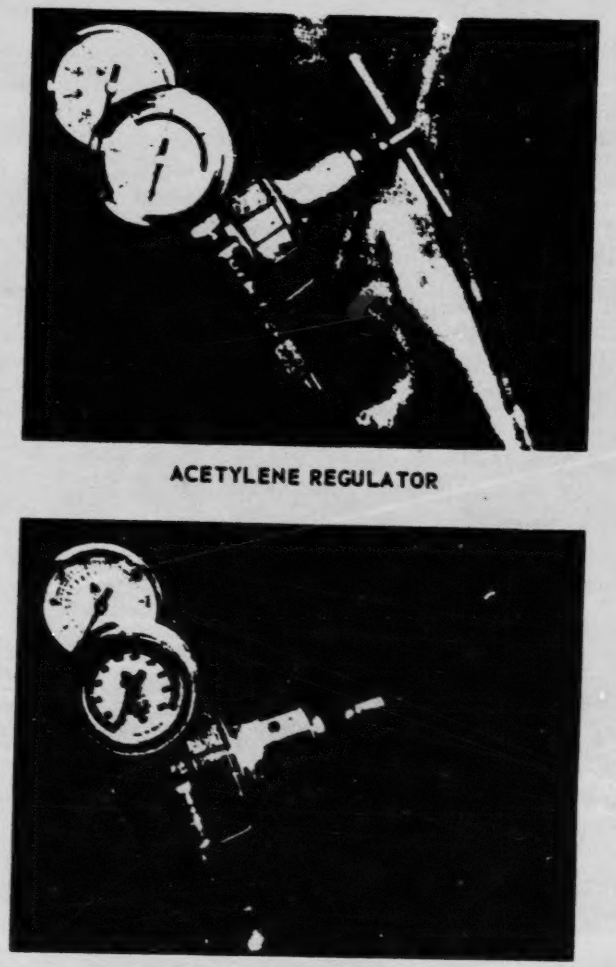
Safety precautions applicable to the handling, use, and stowage of compressed-gas cylinders should be carefully observed. Some of the safety precautions to be observed in working with acetylene and oxygen cylinders are given later in this chapter.

REGULATORS

The gas pressure in a cylinder must be reduced to a suitable working pressure before it can be used. This pressure reduction is accomplished by a regulator or reducing valve. Regulators which control the flow of gas from the cylinder are either of the single-stage or the double-stage type. Single-stage regulators reduce the pressure of the gas in one step, while two-stage regulators perform the same work in two steps or stages. Generally, less adjustment is necessary when two-stage regulators are used.

Figure 8-8 shows two SINGLE-STAGE regulators—one for acetylene and one for oxygen. The regulator mechanism consists of a nozzle through which the high-pressure gases pass, a valve seat to close off the nozzle, a diaphragm, and balancing springs. These are all enclosed in a suitable housing. Pressure gages are provided to indicate the pressure in the cylinder or pipeline (inlet), as well as the working pressure (outlet). The inlet pressure gage, used to record cylinder pressures, is a high-pressure gage, while the outlet pressure gage, used to record working pressures, is a low-pressure gage. Acetylene regulators and oxygen regulators are of the same general type, although those designed for acetylene are not made to withstand as high pressures as are those designed for use with oxygen cylinders.

In the oxygen regulator, the oxygen enters the regulator through the high-pressure inlet connection and passes through a glass wool filter that removes dust and dirt. Turning the adjusting screw IN (to the right) allows the oxygen to pass from the high-pressure chamber to the low-pressure chamber of the regulator, through the regulator outlet, and through the hose to the torch. Turning the adjusting screw to the right INCREASES the working pressure; turning it to the left DECREASES the working pressure. The high-pressure gage is graduated in pounds per square inch from 0 to 3000 and in cubic feet from 0 to 220. This permits reading of the gage to determine cylinder pressure and cubic content. Gages are graduated to read correctly at 70°F. The working pressure gage is graduated in pounds per square inch from 0 to 150 or less, from 0 to 200, or from 0 to 400, depending upon the purpose for which the regulator is designed. For example, on regulators designed for heavy cutting, the working pressure gage is graduated in pounds per square inch from 0 to 400.



ACETYLENE REGULATOR

OXYGEN REGULATOR

11.99

Figure 8-8.—Single-stage regulator.

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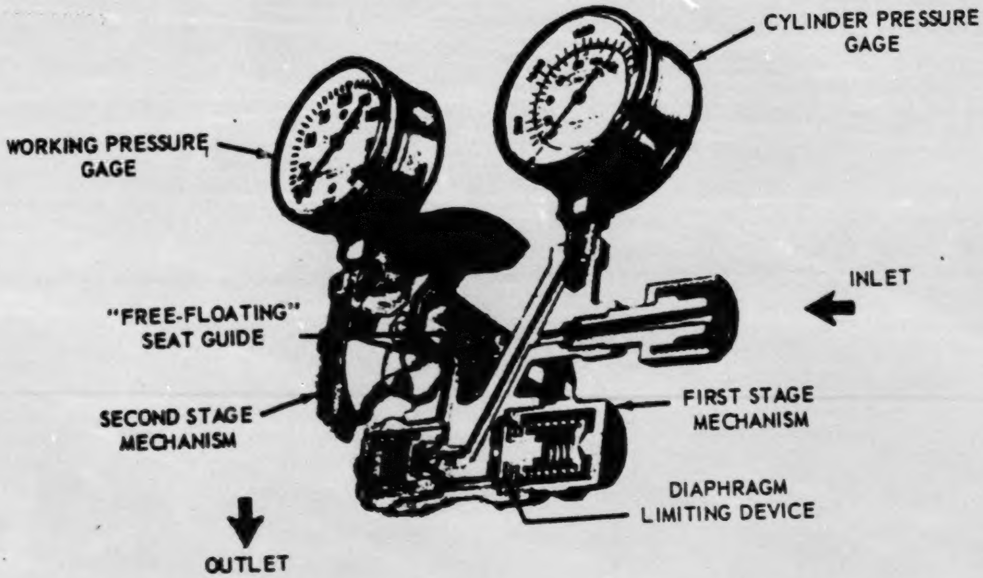
The TWO-STAGE regulator is similar in principle to the one-stage regulator, the chief difference being that the total pressure drop takes place in two steps instead of one. In the high-pressure stage, the cylinder pressure is reduced to an intermediate pressure. In the low-pressure stage, the pressure is reduced from the intermediate pressure to a working pressure. A typical two-stage regulator is shown in figure 8-9.

WELDING TORCHES

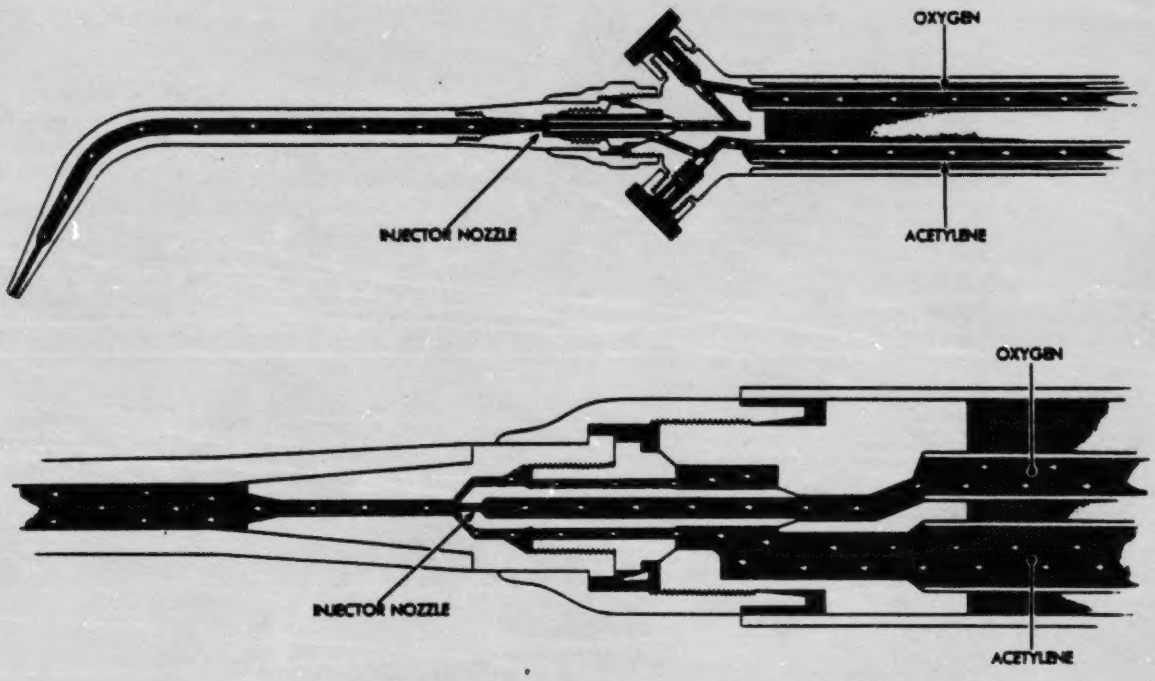
The oxyacetylene welding torch mixes oxygen and acetylene in the proper proportions and controls the amount of the mixture at the welding tip. Torches have two needle valves—one for adjusting the flow of oxygen and the other for adjusting the flow of acetylene. Other basic parts include a handle, two tubes (one for oxygen and another for acetylene), a mixing head, and a tip. On some models the tubes are silver-brazed to the head and the rear end forgings, which are in turn fitted into the handle. Welding tips are made from copper and are available in different sizes to handle a wide range of plate thicknesses.

There are two general types of welding torches—a low-pressure type and a medium-pressure type. In the low-pressure torch, also known as an injector type torch, acetylene pressure per square inch is kept at about 1 pound. The oxygen pressure ranges from about 10 to 40 pounds, according to the size of the torch tip. A jet of relatively high pressure oxygen produces the suction necessary to draw the acetylene into the mixing head. The welding tips may or may not have separate injectors in the tip. A typical mixing head for the low-pressure (or injector-type) torch is shown in figure 8-10.

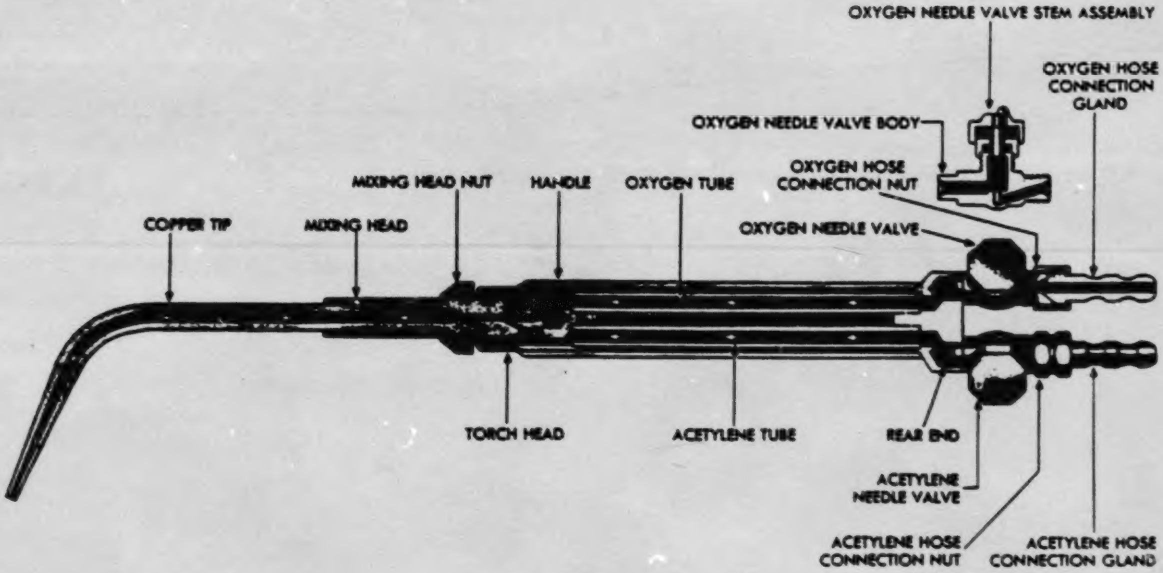
Medium-pressure torches are sometimes called balanced-pressure or equal-pressure types, since the acetylene and the oxygen pressure are kept equal. Pressure per square inch may be from 1 to 6 or 8 pounds; acetylene pressure must never be allowed to go above 15 psi. A typical equal-pressure general-purpose torch is illustrated in figure 8-11. The medium-pressure torch is easier to adjust than the low-pressure torch and, since equal pressures are used for each torch, you are less likely to get a flashback. This means that the flame is less likely to catch in or behind the



11.100
Figure 8-9.—Two-stage regulator.


OXYGEN
INJECTOR NOZZLE
ACETYLENE
OXYGEN
INJECTOR NOZZLE
ACETYLENE

11.101X
Figure 8-10.—Mixing head for low pressure torch.


OXYGEN NEEDLE VALVE STEM ASSEMBLY
OXYGEN HOSE CONNECTION GLAND
OXYGEN NEEDLE VALVE BODY
OXYGEN HOSE CONNECTION NUT
MIXING HEAD NUT
HANDLE
OXYGEN TUBE
COPPER TIP
MIXING HEAD
OXYGEN NEEDLE VALVE
TORCH HEAD
ACETYLENE TUBE
REAR END
ACETYLENE NEEDLE VALVE
ACETYLENE HOSE CONNECTION NUT
ACETYLENE HOSE CONNECTION GLAND

11.102X
Figure 8-11.—Equal-pressure welding torch.

mixing chamber; more details on flashback are given later in this chapter.

Welding TIPS and MIXERS are designed in several ways, depending on the manufacturer. Some makes of torches have a separate mixing head or mixer for each size of tip. Other makes have only one mixer for several tip sizes. Tips come in various types. Some are one-piece, hard copper tips. Others are two-piece tips and include an extension tube to make connection between the tip and the mixing head. When used with an extension tube, removable tips are made of hard copper, brass, or bronze. Tip sizes are designated by numbers, and each manufacturer has his own arrangement for classifying them. Tip sizes differ in the diameter of the hole to obtain the correct volume of heat for the work to be done.

HOSE

Hose used to make connection between the torch and the regulators is strong, nonporous, and sufficiently flexible and light to make torch movements easy. It is made to withstand high internal pressures, and the rubber used in its manufacture is specially treated to remove sulphur to avoid the danger of spontaneous combustion. Welding hose comes in various sizes, depending upon the size of work for which it is intended. Hose used for light work is 3/16 or 1/4 inch inside diameter, and it has one or two plies of fabric. For heavy duty welding and cutting operations, hose with an inside diameter of 5/16 inch and 3 to 5 plies of fabric is used. Single hose comes in lengths of 12-1/2 feet to 25 feet. Some manufacturers make a double hose which conforms to the same general specifications. The hoses used for acetylene and oxygen are the same in grade but they differ in color. Oxygen hose is GREEN, acetylene hose is RED.

CAUTION: Use no oil, grease, or any other lubricant on welding (or cutting) apparatus. Oil or grease in the presence of oxygen under pressure will ignite violently!

FILLER RODS

The term filler rod refers to a filler metal, in wire or rod form, used in gas welding and brazing processes and in certain electric welding processes in which the filler metal is not a part of the electric circuit. A filler rod serves only one purpose: it supplies filler metal to the joint.

Filler rods for steel are often copper coated to protect them from corrosion during storage. Most rods are furnished in 36-inch lengths and a wide variety of diameters, ranging from 1/32 to 3/8 inch. Rods for welding cast iron vary from 12 to 24 inches in length and are frequently square rather than round in cross section. The rod diameter selected for a given job is governed by the thickness of the metals being joined.

Except for rod diameter, the filler rod selected is determined by specification on the basis of the metals being joined. These specifications may be Federal, Military, or Navy specifications. This means that they apply to all Federal agencies, the Military Establishment, or the Navy, respectively. Filler metals are presently covered by one or more of these three types of specifications. Eventually, all Navy specifications will be rewritten as Military (MIL) specifications. For that reason, some of the specifications for welding materials presented in this section may subsequently be published as Military rather than Navy specifications.

Many different types of rods are manufactured for welding ferrous and nonferrous metals. In general, welding shops stock only a few basic types which are suitable for use in all welding positions. These basic types are known as general purpose rods. One such general purpose rod that will be found in any Navy welding shop is a rod suitable for oxyacetylene welding of low carbon steel; this is covered by specification MIL-R-908, class I, type A. The same specification covers filler rods for use on cast iron; in this case, however, a class II rod is used.

Rods for gas welding on other common materials are covered by other specifications. As of the time of writing of this training manual, the following specifications apply: copper-base alloys, MIL-R-19631; corrosion-resisting and heat-resisting steel, MIL-R-5031, class 5; nickel-base alloys, including Monel, QQ-R-571; and nickel-chromium-iron alloys, N:46-R-5. Chromium-cobalt rods for hard-surfacing with the oxyacetylene flame (a special gas welding application) are covered by specification MIL-R-17131.

OPERATION AND MAINTENANCE OF OXYACETYLENE EQUIPMENT

This section discusses basic procedures involved in setting up oxyacetylene equipment, lighting off and adjusting the flame, and securing equipment. Information also is provided on the maintenance of oxyacetylene welding equipment.

SETTING UP THE EQUIPMENT

Setting up the oxyacetylene equipment and preparing for welding must be done carefully and systematically to avoid costly mistakes. To ensure your own safety, as well as that of your co-workers and of equipment, make sure the following steps are taken before any attempt is made to light the torch.

1. Secure the cylinders so that they cannot be knocked over or upset accidentally. A good way to do this is to either put them in a corner or next to a vertical column and then secure them with a piece of line. After securing the cylinders, remove the protecting caps. Cylinders should never be secured to a metal structural member of a building that is a conductor of current.

2. Crack each cylinder valve slightly, being careful to stand to one side when you do so and then almost immediately close the valve again. Do not bleed acetylene into the work-space, where it may become ignited. This instant of opening should be enough to blow the valve out clean. Close the valves and wipe the connection with a clean cloth.

3. Connect the acetylene pressure regulator to the acetylene cylinder, and the oxygen pressure regulator to the oxygen cylinder. Using the wrench provided with the equipment, snug the connection nuts sufficiently to avoid leaks.

4. Back off the regulator screws to prevent damage to the regulators and gages. Open the cylinder valves slowly; open the acetylene valve only one-half turn but open the oxygen valve all the way. You may use a handwheel to open the acetylene valve. In the absence of a hand-wheel, use the wrench provided. Leave the wrench in place while the cylinder is in use so that the acetylene can be turned off quickly in an emergency. Read the high pressure gage to check the contents in each cylinder.

5. Connect the RED hose to the acetylene regulator, and the GREEN hose to the oxygen regulator. Notice the left-hand threads on the acetylene connection.

6. To blow out the oxygen hose, turn in the regulator screw; then turn the screw back out again. If necessary to blow out the acetylene hose, do it ONLY in a well ventilated place FREE FROM SPARKS, FLAMES, or other possible sources of ignition.

7. Connect the hoses to the handle. The RED (acetylene) hose is connected to the connection gland with the needle valve marked AC. The GREEN (oxygen) hose is connected to the connection gland with the needle valve marked OX.

8. With the needle valves closed, turn IN both regulator screws, to test the hose connections for leaks. Turn OUT the regulator screws and drain the hose by opening the needle valves.

9. Select the correct tip and mixing head (for mixing the acetylene and oxygen), and assemble them into the torch body. Tighten the assembly by hand, and then adjust to the proper angle. When the desired adjustment has been obtained, tighten the tip the proper amount. On some types of equipment the tip is tightened with a wrench, while on other types only hand-tightening of the tip is required.

10. Adjust the working pressures. The acetylene pressure is adjusted by opening the acetylene torch needle valve and turning the regulator screw to the right. Adjust the acetylene regulator to the working pressure needed for the particular tip size, and close the torch needle valve. To adjust the oxygen working pressure, open the oxygen torch needle valve and proceed in the same manner as in adjusting the acetylene pressure.

LIGHTING OFF AND ADJUSTING FLAME

Use proper care in lighting the torch. In lighting the torch and adjusting the flame always follow the manufacturer's directions for the particular model of torch being used. This is necessary because the procedure varies somewhat with different types of torches and, in some cases, even with different models made by a single manufacturer.

In general, the procedure followed in lighting a torch is to first open the torch oxygen needle valve a small amount, and the torch acetylene needle valve all the way or somewhat more than the oxygen valve, depending upon the type of torch. The mixture of oxygen and acetylene issuing from the tip is then lighted by means of a spark igniter or stationary pilot flame.

CAUTION: NEVER use matches to light the torch; their length requires bringing the hand too close to the tip. Accumulated gas may envelop the hand and, upon igniting, result in a severe burn. Also, never light the torch from hot metal.

After checking the acetylene pressure adjustment, the oxyacetylene flame can be adjusted so as to have the desired characteristics for the work at hand by further manipulating the oxygen and acetylene needle valves, according to the torch manufacturer's direction.

There are three types of flame commonly used for oxyacetylene processes: neutral, carburizing or reducing, and oxidizing. To ensure proper flame adjustment, you should know the characteristics of each of these three types of flame.

Figure 8-12 illustrates, in color, the appearance of the flame at the tip of the torch at different temperatures, and with different ratios of oxygen to acetylene. This illustration will serve as a guide in determining what type of flame you are obtaining.

A pure acetylene flame has a yellowish color, and is long and bushy, as shown in figure 8-12. It takes the oxygen which it needs for combustion from the surrounding air. The oxygen thus available is not sufficient to completely burn the acetylene, and the smoky flame which results deposits a soot of fine, unburned carbon. Such a flame is NOT suitable for use. You will have to increase the amount of oxygen by opening the oxygen needle valve until the flame takes on a blusih-white color, with a bright inner cone surrounded by a flame envelope of darker hue. It is the inner cone that develops the required operating temperature.

The NEUTRAL flame is produced when equal amounts of oxygen and acetylene are used. Together with the oxygen in the air, this 50-50 ratio provides for complete combustion of the two gases. A neutral flame is obtained by gradually opening the oxygen valve to shorten the acetylene flame until a well-defined, inner luminous, white cone is visible; there is no greenish tinge of acetylene at the tip and no excess of oxygen.

At the tip of the inner cone the temperature will be about 5850° F, but only about 2300° F at the extreme end of the outer cone. This wide variation in temperature makes it possible for the weldor to exercise a certain amount of temperature control simply by moving the torch closer to or farther away from the work.

A neutral flame is the correct flame to use for many metals. It is used for most welding and for the preheating flames during cutting operations. When steel is welded with this flame, the puddle of molten metal is quiet and clear, and the metal flows without boiling, foaming, or sparking. The welding flame should always be adjusted to neutral before either the oxidizing or carburizing flame mixture is set.

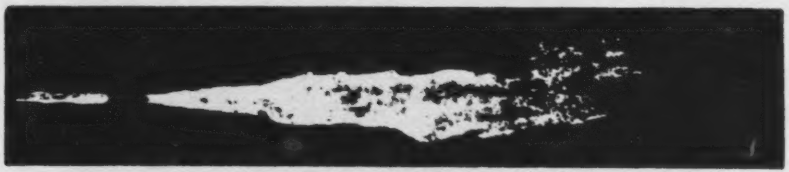
The CARBURIZING, or REDUCING, flame is produced by burning an excess of acetylene. The carburizing flame always shows distinct colors; the inner cone is bluish-white, the intermediate cone is white, the outer envelope flame is light blue, and the feather at the tip of the inner cone is greenish. The length of the feather can be used as a basis for judging the degree of carburization; for most welding operations, the feather should be about twice the length of the inner cone. The temperature at the tip of the inner cone is about 5700° F. When it is used for welding steel, the metal boils and is not clear. A carburizing flame is best for welding high carbon steels, for hard-surfacing, and for welding nonferrous alloys such as Monel.

The OXIDIZING flame is produced by burning about twice as much oxygen as acetylene. You can identify this flame by the short outer flame and the small white, inner cone. It takes about two parts of oxygen to one part of acetylene to produce this flame; this means that adjusting for it is more difficult than for the other flames. After you have obtained a neutral flame, open the oxygen valve until the inner cone is only about 1/10 of its original lenth. Figure 8-12 illustrates how short this cone must be in relation to the overall flame. The inner cone is somewhat pointed and purplish in color at the tip. The flame burns with a hissing sound.

The oxidizing flame has a limited use and is harmful to many metals. When it is applied to steel, the oxidizing flame causes the molten metal to foam and give off sparks. This means that the extra amount of oxygen is combining with the steel, causing the metal to burn. However, the oxidizing flame does have its use. A slightly oxidizing flame is used to torch braze steel and cast iron, and stronger oxidizing flame is used for fusion welding of brass and bronze. You will have to determine the amount of excess oxygen to use in this type of flame adjustment by watching the molten metal.

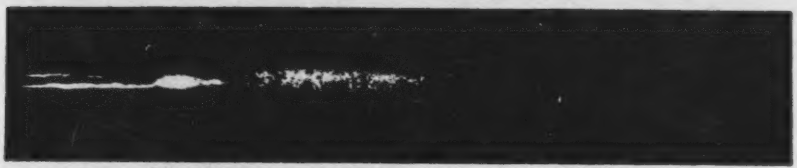
SECURING EQUIPMENT

To extinguish the oxyacetylene flame and to secure equipment after completing a job, or

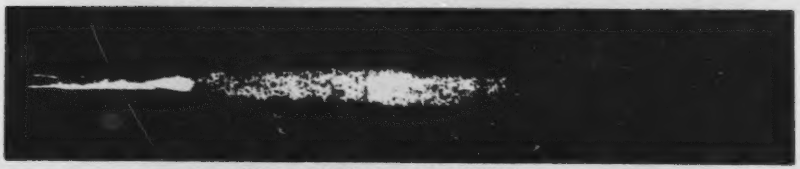


Acetylene burning in air. 1,500° F.

Strongly Carburizing Flame. 5,700° F.



Slight Excess Acetylene Flame. 5,800° F.



Neutral Flame. 5,850° F.

Oxidizing Flame. 6,300° F.

Courtesy Air Reduction Sales Co.

C11.102.0X

Figure 8-12.—Characteristics of oxyacetylene flame.

when work is to be interrupted temporarily, take the following steps:

1. Close the acetylene needle valve first, then close the oxygen needle valve. This extinguishes the flame.

2. Close both oxygen and acetylene cylinder valves. Leave the oxygen and acetylene regulators open temporarily.

3. Open the acetylene needle valve on the torch and allow gas in the hose to escape (5-15 seconds) to the outside atmosphere. Do not allow gas to escape into a small or closed compartment. Close the acetylene needle valve.

4. Open the oxygen needle valve on the torch and allow gas in the hose to escape (5-15 seconds). Close the valve.

5. Close both oxygen and acetylene cylinder regulators by backing out the adjusting screws until they are loose.

Follow the above procedure whenever work is interrupted for an indefinite period. If work is to stop for only a few minutes, securing cylinder valves and draining the hose is not necessary. However, for any indefinite work stoppage, follow the entire extinguishing and securing procedure. For overnight work stoppage in areas other than the shop, it is safer to remove pressure regulators and torch from the system. Double check the cylinder valves to make sure they are closed securely.

MAINTENANCE OF EQUIPMENT

Welding equipment must be given the proper maintenance and upkeep if it is to operate at peak efficiency and give useful service over a maximum period of time. You will not be required to make repairs to welding equipment; but when repairs are needed, consider it your responsibility to see that the equipment is removed from service and turned in for repair. You will, of course, be responsible for various duties involving the maintenance and care of oxyacetylene welding equipment. This section will brief you on some of the common types of maintenance duties that you can expect to perform.

In regard to welding torches, see that they are kept away from oil and grease. At times the needle valve may fail to shut off when hand tightened in the usual manner. When this happens, do not use a wrench to tighten the seat in the valve stem. If foreign matter cannot be blown off the seat, it will be necessary to remove the stem assembly and wipe the seat clean before reassembling. Be sure and keep the mixer seat free of dust, dirt, and other foreign matter.

Before a new torch is used for the first time, it is a good idea to check the packing nut on the valves to make sure it is tight. The reason is that some manufacturers ship torches with these nuts loose.

A common trouble with torches in oxyacetylene welding is that the orifice in the torch tip becomes clogged with slag and the flame fails to burn properly. The remedy for clogging is to clean the orifices thoroughly. Clogging often is caused by holding the tip too close to the surface of the metal when starting a cut. When this practice is followed, the blowing action of the oxygen blast tends to bounce the molten metal and slag from the cut back up to the torch tip, thus causing the orifices to become clogged. It is wise to always inspect the tip before using; and, if the orifice is clogged, clean it thoroughly before starting to weld.

For best results in cleaning the orifice of the welding tip use a twist drill of the proper size, or a soft brass or copper wire. A cleaning drill about one size smaller than the tip orifice is an ideal selection when this tool is to be used for the cleaning operation. Give special attention to drill size to avoid enlarging the orifice. When using the tip cleaner, remember to push it straight in and out of the hole—DO NOT rotate it.

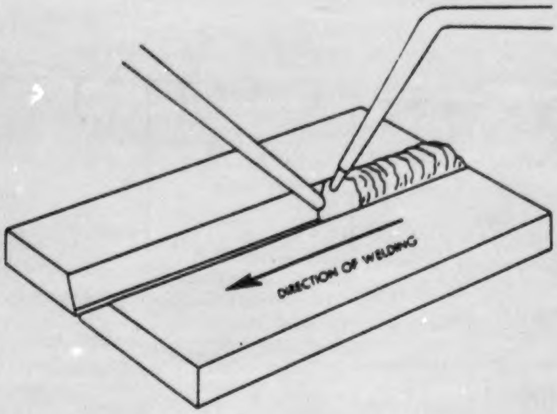
Should the end of the torch tip become rough and pitted and the orifice become oversized (bell-mouthed), you should recondition the tip. Place a piece of emery cloth, grit side up, on a flat surface; hold the tip perpendicular to the emery cloth, and rub it back and forth just enough to true the surface and to bring the orifice back to its original diameter.

If there is leakage around the TORCH VALVE STEM, tighten the packing nut, and repack if necessary. For repacking, make sure you use only packing recommended by the manufacturer of the torch concerned. DO NOT USE ANY OIL. If the valve stem happens to be bent or badly worn, replace it with a new stem.

A symptom of LEAKY VALVES is a continuing flow of gases after the valves are closed. Leaky valves often are caused by a dirty or damaged seat. To clean the seat, remove the valve assembly and wipe the seating portions of both valve stem and valve body with a clean rag. If the leak continues, try closing the valve tightly several times. If these measures fail to stop the leak, parts may have to be replaced or the valve body may have to be reseated; these repairs should be made only by qualified personnel.

Leaks in the MIXING-HEAD SEAT of the torch will cause oxygen and acetylene leaks between the inlet orifices leading to the mixing-head. This defect may cause improper mixing of the gases, and result in flashbacks. This defect can be corrected by reaming out the seat in the torch head and by truing the mixing-head seat. It may be necessary to send the equipment to the manufacturer for these repairs, since special reamers are required for truing seats.

With regulators, you will probably find that gas leakage between the REGULATOR SEAT and NOZZLE is a common type of trouble. This defect can be detected by a gradual rise in pressure on the working-pressure gage when the adjusting screw is fully released or is in position after adjustment. Frequently, this trouble, known as CREEPING REGULATOR, is caused by worn or cracked seats. It also can be brought on by foreign matter lodged between the seat and the nozzle. It is important that regulators with leaks across the seats be repaired at once; otherwise damage to other parts of the regulator or apparatus may result. This is particularly dangerous where acetylene regulators are concerned, because acetylene at a very high pressure in the hose becomes an explosive hazard. To ensure the safety of personnel and equipment, see that regulators with such leaks are removed from service and turned in for repair.



11.103
Figure 8-13.—Forehand welding.

OXYACETYLENE WELDING TECHNIQUES

Oxyacetylene welding may be accomplished by either the forehand or the backhand method. Each of these techniques has special advantages; you should be skillful with both. Whether a technique is considered to be forehand or backhand depends on the relative position of the torch and rod during welding, not upon the direction of welding. As far as direction is concerned, you can weld from left to right or in the opposite direction. The best method to use depends upon the type of joint, its position, and the necessity for controlling the heat on the parts to be welded.

FOREHAND WELDING—sometimes referred to as PUDDLE welding or RIPPLE welding—is the older method still in use. (See fig. 8-13.) The rod is kept ahead of the flame in the direction in which the weld is being made. You point the flame in the direction of the welding, and hold the tip at an angle of about 45 degrees to the working surfaces. With your other hand, move the rod in the same direction as the tip. You can melt the end of the rod and the weld surfaces into a uniformly distributed molten puddle if you move the torch tip and the rod in opposite semicircular paths. The flame preheats the edges you are welding, just ahead of the molten puddle; and as it passes the rod, it melts a short length of that, and adds it to the puddle. You will have to practice with the torch until you are able to distribute the molten metal evenly to the puddle and along both edges of the joint. This method is used in all positions for welding sheets and light plates up to 1/8 inch thick because it permits better control of a small puddle and results in a smoother weld. The forehand technique is not the best method for welding heavy plate.

BACKHAND WELDING is a newer method of welding. In this method the flame precedes the rod in the direction of welding, and the flame is pointed back at the molten puddle and the completed weld. The end of the rod is placed between the torch tip and the molten puddle, and the welding tip should make an angle of about 60° with the plates or joint being welded (see fig. 8-14).

Less motion is required in the backhand method than in the forehand method. If you use a straight welding rod, it should be rotated so that the end will roll from side to side and melt off evenly. You may also bend the rod and, when welding, move the rod and torch back and forth at a rather rapid rate. If you are making a large weld, you should move the rod so as to make complete circles in the molten puddle. The torch is moved back and forth across the weld while it is advanced slowly and uniformly in the direction of the welding. You'll find the backhand method best for welding material more than 1/8 inch thick. You can use a narrower V at the joint than is possible in forehand welding. An included angle of 60° is a sufficient angle of bevel to get a good joint. It doesn't take as much welding rod or puddling for the backhand method as it does for the forehand method.

CHAPTER 9

OXYACETYLENE CUTTING

The construction of the oxyacetylene cutting torch is discussed in this chapter. The procedures used in various oxyacetylene cutting operations also are explained.

The oxyacetylene cutting torch has a number of applications in steelwork. At most any naval activity the Steelworker will find the cutting torch an excellent tool for cutting ferrous metals. This versatile tool can be used for such operations as beveling plate, cutting and beveling pipe, piercing holes in steel plate, and cutting wire rope.

In the oxyacetylene cutting process a spot on the metal to be cut is heated to kindling or ignition temperature (between 1400° and 1600° for steels) by oxyacetylene flames, also called preheating flames. Then a jet of pure oxygen under pressure is directed at the metal, and a chemical reaction known as OXIDATION takes place. When oxidation occurs rapidly it is called COMBUSTION or BURNING; when it occurs slowly, it is called RUSTING. When metal is being cut by the oxyacetylene torch method, the oxidation of the metal is extremely rapid—in short, the metal actually burns. The heat liberated by the burning of the iron or steel melts the iron oxide formed by the chemical reaction, and also heats the iron or steel. The molten material runs off as slag, exposing more iron or steel to the oxygen jet.

In oxyacetylene cutting, only that portion of the metal which is in the direct path of the oxygen jet is oxidized. Thus, a narrow slit, called a KERF, is formed in the metal as the cutting progresses. Most of the material removed from the kerf is in the form of oxides (products of the oxidation reaction); the remainder of the material removed from the kerf is molten metal which is blown or washed out of the kerf by the force of the oxygen jet.

While making the cut, you will have to keep the preheating flames of the cutting torch burning so that the kerf will progress smoothly. The heat generated by the chemical reaction should be sufficient for preheating the metal; but owing to the rapid radiation caused by dirt, scale, and paint, preheating is necessary.

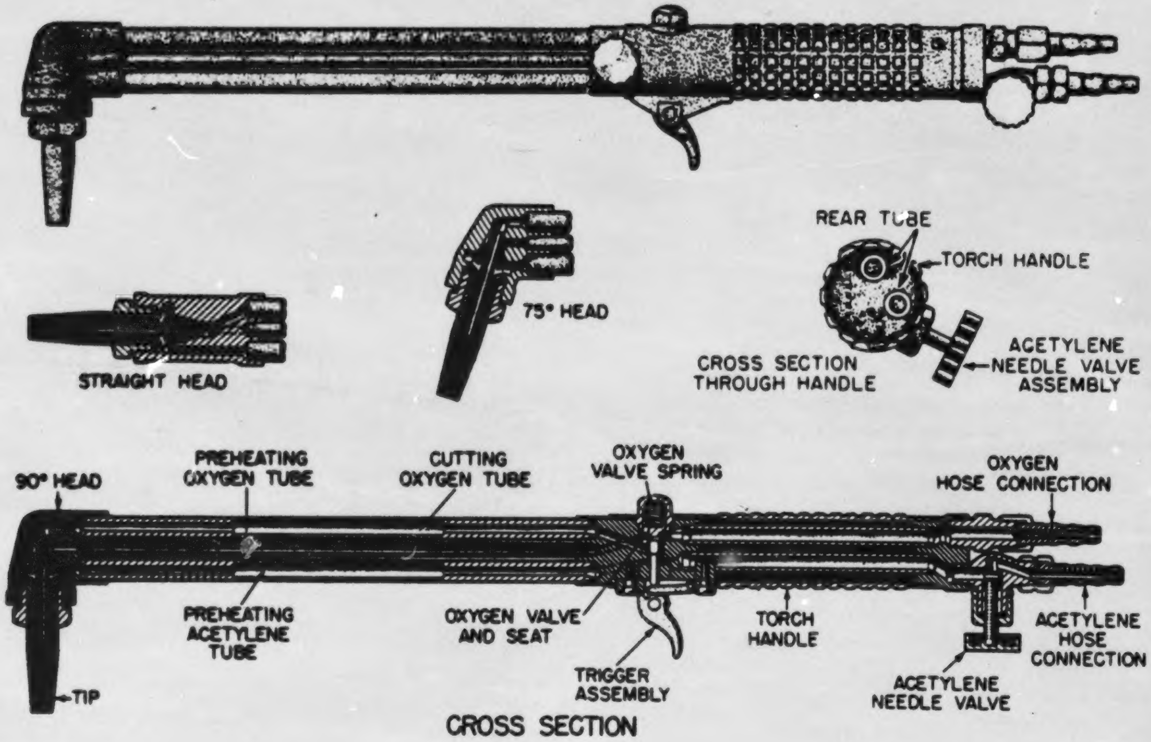
Since oxidation of the metal is a vital part of the oxyacetylene cutting process, this process is not suitable for metals which do not oxidize readily. Carbon steels are readily cut by the oxyacetylene cutting process; but special techniques (described later in this chapter) are required for the oxyacetylene cutting of many other metals.

The walls of the kerf formed by oxyacetylene cutting of ferrous metals should be fairly smooth and parallel to each other. When you develop skill in handling the torch, you will be able to hold the cut to within reasonably close tolerances. Also, you will be able to guide the cut along straight, curved, or irregular lines, and to cut bevels or other shapes which require holding the torch at an angle.

CUTTING TORCHES

The equipment and accessories for oxyacetylene cutting are the same as for oxyacetylene welding except that a cutting torch, or a cutting attachment, instead of a welding torch is used. A main difference between the cutting torch and the welding torch is that the cutting torch has an additional tube for high pressure (cutting) oxygen. The flow of high pressure oxygen can be controlled from a valve on the handle of the cutting torch. In the standard cutting torch, the valve may be in the form of a trigger assembly like the one in figure 9-1. On most makes of torches, the cutting oxygen mechanism is designed so that the cutting oxygen can be eased on gradually. This gradual opening of the cutting oxygen valve is particularly helpful in operations such as hole piercing and rivet cutting.

Most welding torches are furnished with a cutting attachment which may be fitted to the handle in place of the welding tip. With this


REAR TUBE
TORCH HANDLE
STRAIGHT HEAD
75° HEAD
CROSS SECTION THROUGH HANDLE
ACETYLENE NEEDLE VALVE ASSEMBLY
90° HEAD
PREHEATING OXYGEN TUBE
CUTTING OXYGEN TUBE
OXYGEN VALVE SPRING
OXYGEN HOSE CONNECTION
PREHEATING ACETYLENE TUBE
OXYGEN VALVE AND SEAT
TORCH HANDLE
ACETYLENE HOSE CONNECTION
TIP
TRIGGER ASSEMBLY
ACETYLENE NEEDLE VALVE
CROSS SECTION

11.125
Figure 9-1.—Oxyacetylene cutting torch.

type of attachment, the welding torch may be used as a cutting torch. This type of torch is generally called a combination torch, because you do not have to disconnect the handle at the hoses. On a combination torch the high pressure oxygen is controlled by a lever on the handle, as illustrated in figure 9-2.

CUTTING TIPS

Cutting tips are made of copper or of tellurium-copper alloys. Whether you use a cutting torch or a cutting attachment to the welding handle, the cutting tip (or nozzle) will be of the same general design as that shown in figure 9-3. Notice that the cutting tip has a number of small orifices (holes) which surround a larger center orifice. The small orifices are for the oxyacetylene flames which are used to preheat the metal to its ignition temperature. The large center orifice is used to direct the jet or stream of high pressure oxygen that does the cutting. There are usually four or six preheat orifices in each oxyacetylene cutting tip; however, some heavy-duty tips have many more preheat orifices.

Cutting tips are furnished in various sizes. In general, the smaller sizes are used for cutting thin metal and the larger sizes are used for cutting heavy metal. Tip sizes are identified by numbers. When numbers such as 00, 0, 1, 2, 3, 4, and 5 are used to identify tip sizes, the lower numbers indicate the smaller tips; for example, a 00 tip is smaller than a number 1 tip, and a number 1 tip is smaller than a number 5 tip. Some manufacturers identify cutting tips by giving the drill size number of the orifices. Large drill size numbers indicate small orifices; for example, drill size 64 is smaller than drill size 56.

In military specifications and standards, oxyacetylene cutting tips are identified by three-part numbers. The first part is the tip size (0, 1, 2, 3, etc.). The second part is the drill size number

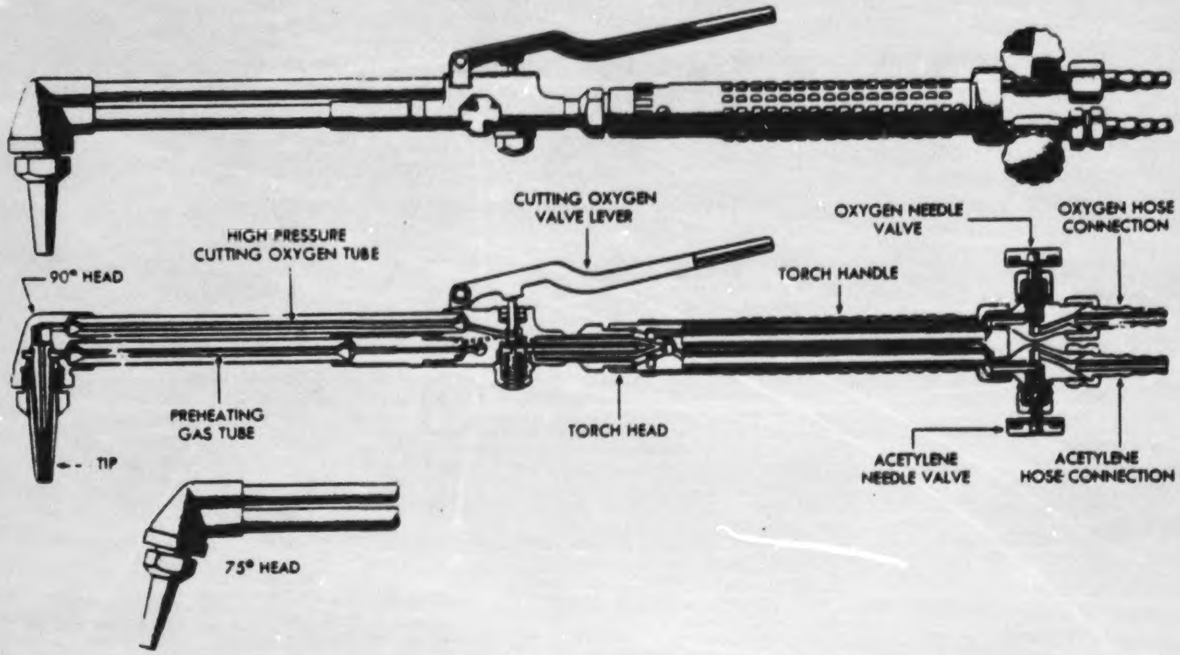

CUTTING OXYGEN VALVE LEVER
OXYGEN NEEDLE VALVE
OXYGEN HOSE CONNECTION
HIGH PRESSURE CUTTING OXYGEN TUBE
90° HEAD
TORCH HANDLE
PREHEATING GAS TUBE
TORCH HEAD
TIP
ACETYLENE NEEDLE VALVE
ACETYLENE HOSE CONNECTION
75° HEAD

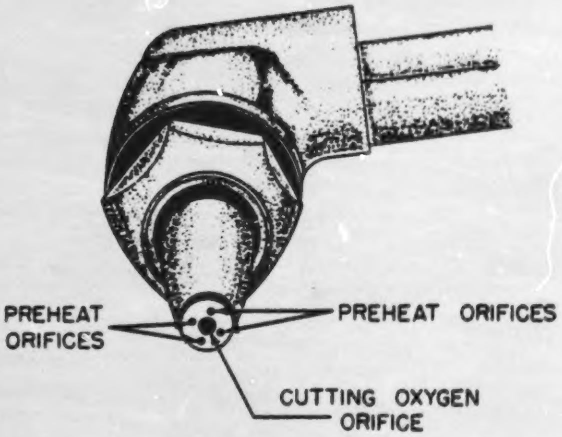
Figure 9-2.—Cutting attachment for an oxyacetylene welding torch.

of the orifice for the cutting oxygen. The third part is the drill size number of the preheat orifices. For example, the number 1-62-64 identifies a number 1 tip with a cutting oxygen orifice of drill size 62 and preheat orifices of drill size 64.

Table 9-1 gives tip numbers, orifice sizes, and approximate cutting ranges of various sizes of oxyacetylene cutting tips.

CARE OF TIPS

In cutting operations the stream of cutting oxygen sometimes will blow slag and molten metal into the orifices and cause them to become partly clogged. When this happens, the orifices should be thoroughly cleaned before the tip is used again; even a very small amount of slag or metal in an orifice will seriously interfere with the cutting operation. The recommendations of the torch manufacturer should be followed as to the size of drill or tip cleaner to use for cleaning the orifices. If you do not have a tip cleaner or drill, then you may use a piece of soft copper wire. Do not use twist drills,


PREHEAT ORIFICES
PREHEAT ORIFICES
CUTTING OXYGEN ORIFICE

11.127X
Figure 9-3.—Oxyacetylene cutting tip.

11.387

Table 9-1.—Sizes and Cutting Ranges of Oxyacetylene Cutting Tips

Tip Identification	Cutting Oxygen Orifice (Drill Size)	Preheat Orifices	Approximate Cutting Range, Straight Edge Cutting of Medium Steel (Inches)
		Drill Size	
1-62-64	62	64	1/8 to 1/2
2-56-62	56	62	1/4 to 1 1/4
3-52-59	52	59	1 to 2 1/2
4-43-57	43	57	2 to 6
5-30-56	30	56	6 to 12

nails, or welding rods for cleaning tips, as these are likely to enlarge and distort the orifices.

The orifices of the cutting torch tip are cleaned in the same manner as the single orifice of the welding torch tip. Remember that the proper technique for cleaning is to push the cleaner straight in and out of the orifice; be careful not to turn or twist it.

Occasionally the cleaning of the tips will cause enlargement and distortion of the orifices even if the proper tip cleaners are used. If the orifices become enlarged you will get shorter and thicker preheating flames; in addition, the jet of cutting oxygen will spread rather than leave the torch in the form of a long thin stream. If the orifices become belled, for a very short distance at the end, it is sometimes possible to correct this condition by rubbing the tip back and forth against emery cloth on a flat surface. This wears down the end of the tip where the orifices have been belled, thus bringing the orifices back to their original size. Obviously, this procedure would not work if the enlargement is very great or if the belling extends more than a slight distance into the orifice.

After reconditioning a tip, test it by lighting the torch and observing the preheating flames. If the flames are too short, the orifices are still partially blocked. If the flames snap out when the valves are closed, the orifices are still distorted.

If the tip seat is dirty or scaled so that it does not fit properly into the torch head, heat the tip to a dull red and quench it in water. This will loosen the scale and dirt enough so that they can be rubbed off with a cloth.

OXYACETYLENE CUTTING OPERATIONS

Before beginning a cutting operation with an oxyacetylene cutting torch, a thorough inspection of the area should be made. There should be no combustible material which could be ignited by the sparks and slag produced by the cutting operation. If you are burning into a wall, inspect the opposite side of the wall and post a man as required.

Select the proper size tip and insert it in the cutting torch. Then adjust the oxygen and acetylene pressures for the thickness of material to be cut. Remember that the tip size and pressures should be in accordance with the cutting torch manufacturer's recommendations.

Put on goggles and gloves. Of course, additional safety apparel should also be worn if required for the job at hand. Light the torch with the spark igniter that is used to light the welding torch. You can tell you have the torch lit properly when you cut on the oxygen and get a neutral flame prior to squeezing the trigger, and the preheating flames stay uniform in size and do not attempt to leave the torch.

CUTTING LOW CARBON STEEL

To cut low carbon steel with the oxyacetylene cutting torch, adjust the preheating flames to neutral. Hold the torch perpendicular to the work, with the inner cones of the preheating flames about 1/16 inch above the end of the line to be cut, as shown in figure 9-4. Hold the torch in this position until the spot you are heating is a bright red. Open the cutting oxygen valve slowly but steadily. If the cut is being started correctly, a shower of sparks

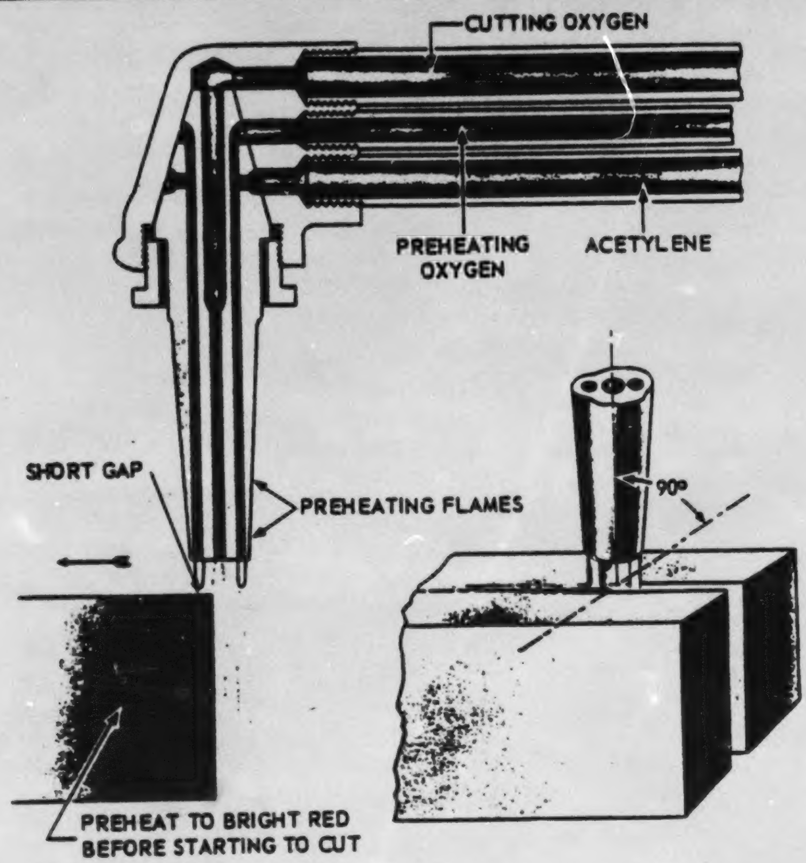


Figure 9-4.—Position of torch tip for starting a cut. 11.128X

will fall from the opposite side of the work, indicating that the cut is going all the way through. Move the cutting torch forward along the line just fast enough for the cut to continue to penetrate the work completely. If you have made the cut properly, you will get a clean, narrow cut which looks somewhat like one made by sawing. When cutting round bars or heavy sections, you can save time if you raise a small burr with a chisel where the cut is to start. This small raised protion will heat quickly, and cutting can be started immediately.

If you have a cut to start from the center or some portion of metal other than the edge, use the following method for starting the cut. Preheat to a bright red the spot on the surface where the cut is to start. Tilt the torch at an angle of about 45° from the perpendicular, in line with the direction of the cut. Open the cutting oxygen valve very slowly. As the torch begins to cut, start righting it to a perpendicular to the surface of the plate. Continue to right the position of the torch gradually as it cuts until it is at 90° to the surface of the plate and is cutting all the way through. Move it forward along the line of cut as fast as complete penetration can be accomplished. If you do not follow this procedure, you are likely to blow the slag back on the cutting tip, clogging the orifices or otherwise damaging the equiment.

When you have started a cut, move the torch slowly along the cutting mark or guide. As you move the torch along, watch the cut so you can tell how it is progressing. Make torch adjustments if necessary. You must move the torch along at the right speed—not too fast, and not too slow. If you go too slowly, the preheating flame will melt the edges along the cut and may even weld them back together at the top surface. If you go too fast, the oxygen will not penetrate completely through the metal and the cut will be incomplete. You will know this right away because sparks or slag will blow back towards you. If you have to restart the cut, make sure there is no slag on the opposite side.

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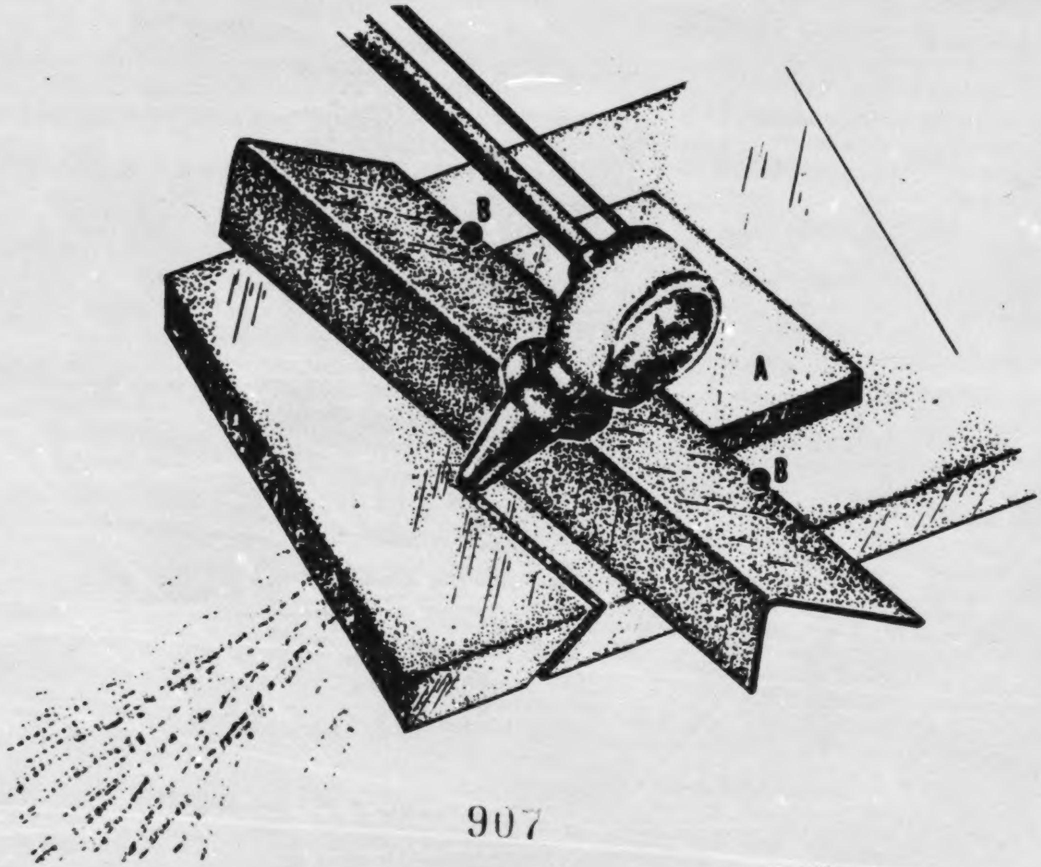
BEVELING PLATE

You will frequently have to cut bevels to form joints for welding. To make a bevel cut of 45° in 2-inch steel, the flame must actually cut through 2.8 inches of metal. Consider this when selecting the tip and adjusting the pressures. You will have to use more pressure and less speed for a bevel cut than for a straight cut.

When you are going to do bevel cutting, adjust the tip so that the preheating orifices straddle the cut. A piece of 1-inch angle iron, with the angle up, makes an excellent guide for beveling straight edges. To keep the angle iron in place while the torch is moving along it, you may use a heavy piece of scrap, as shown in figure 9-5A. Or you can tack weld the angle to the plate being cut, as shown in figure 9-5B. Pull the torch along this guide as shown in figure 9-5.

CUTTING BY MACHINE

In most battalions you may have a cutting machine similar to that shown in figure 9-6. A cutting machine consists of a frame supported by wheels with a movable arm upon which a torch is mounted. Some adjustments up and down and back and forth are necessary to adjust the torch for height and alignment. The wheels are so arranged that they can be mounted upon a track. The machine is motor driven with an adjustable speed motor and a gage is provided to indicate speed. The torch is adjustable out



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11.129
Figure 9-5.—Bevel cutting with oxyacetylene torch.

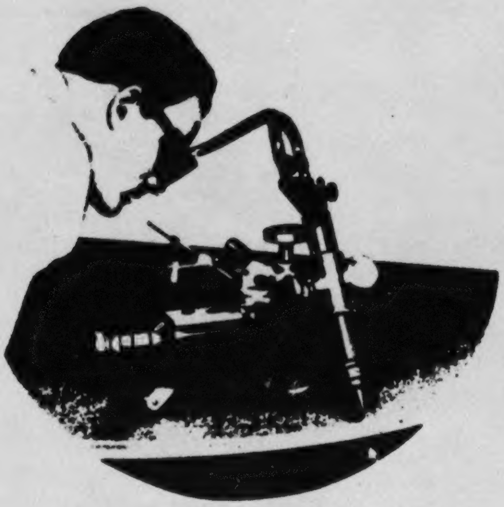

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Figure 9-6.—Bevel cutting on a circular path with special cutting machine.

of the perpendicular to permit the cutting of bevels and the making of angular cuts.

You will find the cutting machine a valuable asset when you are deployed and your shop is called upon to produce a supply of identical parts in quantity. Such an assignment might involve the fabrication of a large supply of hand hole covers for runway fixtures. Another assignment might involve production of a large quantity of thick base plates for vertical columns or bents to be used in precast concrete construction.

When using a cutting machine, a track is laid along the edge of a plate to be cut in a straight line. Then as the oxygen torch valve is opened, the current is turned on, and movement of the machine along the track begins. The machine will continue to cut automatically until the end of the cut is reached. When the cut is complete the operator should promptly cut off the cutting oxygen, turn off the current and extinguish the flame—in that order. The speed of cutting depends upon the thickness of the steel being cut. This same machine can be used for cutting circular lines without the use of the track and with an attachment called a radial bar. A punch mark is made to indicate the center of the circle to be cut and the machine operates around this center point. The machine can be adjusted so that the torch will cut the size of circle desired.

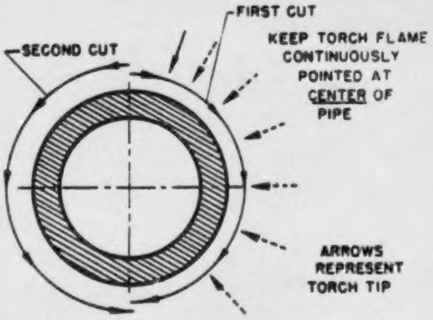
CUTTING AND BEVELING PIPE

When you are cutting a piece of pipe, keep the torch pointed toward the centerline of the pipe. Start the cut at the top and cut down one side. Then begin at the top again and cut down the other side, finishing at the bottom of the pipe. The procedure is shown in figure 9-7.

Pipe cutting with the cutting torch requires a steady hand to get a good bevel cut—one that is smooth and true. Do not try to cut and bevel a heavy pipe in one operation until you have developed considerable skill. Cut the pipe off square first, and make sure you remove all slag from inside the pipe. Then proceed to bevel the pipe. This procedure will produce a cleaner and better job for the inexperienced burner.

Sometimes it is necessary to make T and Y fittings from pipe. Here the cutting torch is a most valuable tool. The usual procedure for fabricating pipe fittings is to develop a pattern like that shown in figure 9-8. Information on pattern development is given in earlier portions of this training manual; if you need additional information or assistance consult your leading petty officer.

After the pattern is developed, it is wrapped around the pipe as illustrated in figure 9-8. Be sure to leave enough stock so that the ends will overlap. Trace around the pattern with soapstone or a scriber. It is a good idea to mark the outline with a prick punch, using light taps, at about 1/4-inch intervals. When the metal is heated during the cutting procedure, the punch


FIRST CUT
SECOND CUT
KEEP TORCH FLAME CONTINUOUSLY POINTED AT CENTER OF PIPE
ARROWS REPRESENT TORCH TIP

11.131
Figure 9-7.—Cutting pipe with oxyacetylene cutting torch.

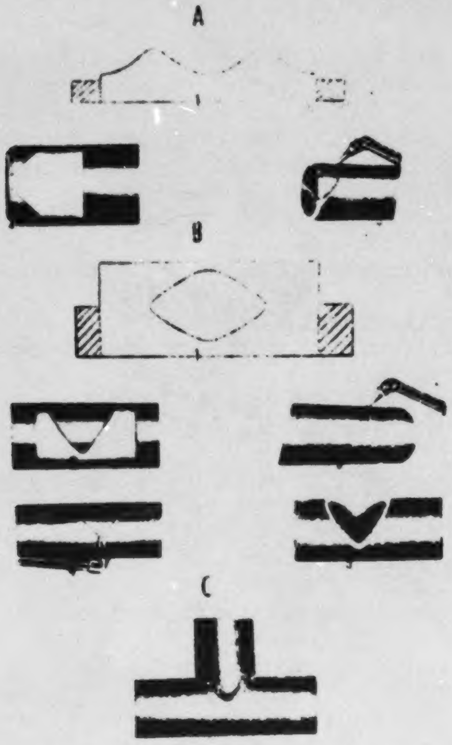


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Figure 9-8.—Fabricating a T.

marks will stand out, making it easier to follow the line of cut. Place the punch marks so that they will be removed during cutting. If punch marks are not removed, they provide notches from which cracking may start.

An experienced burner can cut and bevel pipe at a 45° angle in one operation. A man with little experience may have to do the job in two steps. In that case the first step is to cut the desired pattern at a 90° angle. The second step is to bevel the edge of the cut to a 45° angle. When employing the two-step procedure, another line must be marked on the pipe. This second line follows the contour of the line traced around the pattern, but it is drawn away from the original pattern line at a distance equal to the pipe wall thickness. The first (or 90°) cut in the two-step procedure is made along the second line. The second (or 45°) cut is made along the original pattern line. The two-step procedure is time consuming and uneconomical in terms of oxygen and acetylene consumption.

The one-step cutting and beveling procedure is not complicated, but a steady hand and a great deal of practice are necessary to turn out a first class job. The one-step procedure for cutting and fabricating a T is illustrated in figure 9-8. Part A of figure 9-8 outlines the step by step procedures for producing the branch; part B shows the steps for preparing the other section of the T; and part C shows the assembled T, tack welded and ready for welding.

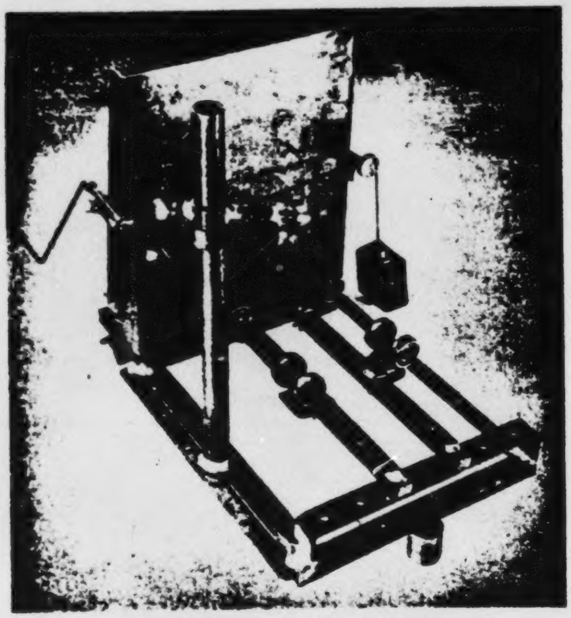
Step 3 under part A shows the procedure for cutting the miter on the branch. The cut is started at the end of the pipe and worked around until one-half of one side is cut. The torch is manipulated so that at all times the tip is at an angle of 45° to the surface of the pipe along the line of cut. While the tip is at a 45° angle, the torch is moved steadily forward and at the same time the butt of the torch is swung upward through an arc. This torch manipulation is necessary to keep the cut progressing in the proper direction, and to produce a bevel that will be 45° at all points on the miter. The second portion of the miter is cut in the same manner as the first.

The torch manipulation necessary for cutting the run of the T is shown in steps 3 and 4 in part B of figure 9-8. Step 3 shows the torch angle for the starting cut. At step 4, the cut has progressed to the lowest point on the pipe. Here the angle has been changed to get around the sharp curve and start the cut in an upward direction. The completed cut for the run is shown in step 5 (part B, fig. 9-8).

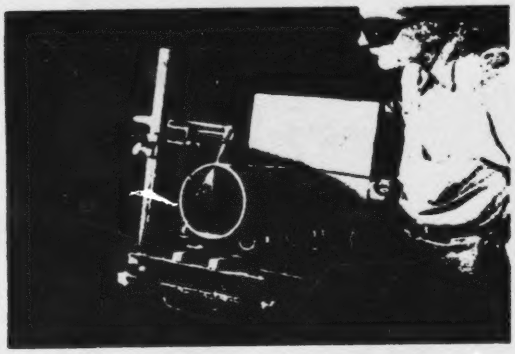
Before the parts of any fabricated fitting are assembled and tack welded, be sure to clean the slag from the inner pipe wall and check the fit of the joint. The bevels must be smooth in order to allow complete fusion when the joint is welded.

If you have a lot of pipe beveling to do and you don't have a special cutting machine, you can—with a little SEABEE ingenuity—fabricate a home-made rig like that shown in figure 9-9. To make this rig, you simply mount, with wing nuts, the rollers from an old pair of roller skates between two pairs of parallel bars welded to a suitable frame.

As an example of how you would use this rig, suppose you have some 6-inch pipes to cut. As the first step, place the pipe on the rollers and mount the cutting torch in the adjustable bracket, as shown in figure 9-10. Using a stout cord, then take a turn around the far end of the pipe. Attach one end of the cord to the crank, which can be made from a piece of one-quarter inch welding



145.181X
Figure 9-9.—A home-made pipe beveling rig.



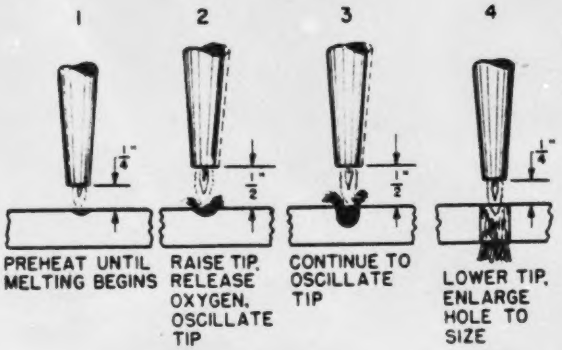
145.182X
Figure 9-10.—Bevels of any angle can be cut with rig.

rod. Pass the other end of the cord over the idler pulley at the right (see fig. 9-10), and attach it to a weight so that the cord will be kept taut. Now proceed to adjust the height of the crank and the idler so that they are slightly lower than the top of the pipe. This adjustment will give the cord a better grip on the pipe and avoid any tendency of the pipe to be lifted off the rollers. Adjust the torch head to an angle of 45 degrees.

Next, light the torch and adjust the flame. Then swing the torch toward the end of the pipe until the preheating flames just touch the edge. As soon as a small area of metal is bright red, open the cutting-oxygen valve and swing the torch into the line of the cut and, at the same time, start turning the crank, thus rolling the pipe. You will soon be able to judge the correct speed and to hold it throughout the cutting operation. Tilt the rig slightly by propping up the forward end; this is done so that gravity will keep the far end of the pipe against the face plate. Smooth, even cuts are easily made with this setup. An advantage is that pipe ends can be cut either straight or with bevels of any desired angle by merely adjusting the angle of the torch head. After cutting, check to ensure that no slag or icicles remain on the inside of the pipe.

PIERCING HOLES

The cutting torch is also a valuable tool for piercing holes in steel plate. The steps are illustrated in figure 9-11. Lay the plate out on two firebricks so that the flame will not hit something else when it burns through the plate. Hold the torch over the hole location with the tips of the inner cone of the preheating flames about 1/4 inch above the surface of the plate. Continue to hold the torch in this position until a small round spot has been heated to a bright red. Open the cutting oxygen valve


1
2
3
4
1/4"
1/2"
1/2"
1/4"
PREHEAT UNTIL MELTING BEGINS
RAISE TIP, RELEASE OXYGEN, OSCILLATE TIP
CONTINUE TO OSCILLATE TIP
LOWER TIP, ENLARGE HOLE TO SIZE

11.133
Figure 9-11.—Piercing a hole with oxyacetylene cutting torch.

very gradually and, at the same time, slightly raise the nozzle away from the cutting tip. As you start raising the torch and opening the oxygen valve, start rotating the torch with a slow spiral motion. This will cause the molten slag to be blown out of the hole. The hot slag may fly around, so BE SURE that your goggles are well fitted to your eyes and face, and avoid having your head directly above the cut.

If you need a larger hole, outline the edge of the hole with a piece of soapstone, and follow the procedure given above. Start the cut from the hole that you have pierced by moving the preheating flames to the normal distance and working to and following the line that has been drawn on the plate. Round holes can be made by using a cutting torch with a radius bar attachment.

CUTTING RIVETS

When you are required to remove rivets from plates that are to be disassembled, you will find the cutting torch a good tool. The cutting procedure is shown in figure 9-12. Use the preheating flames of the cutting torch to bring the head of the rivet up to the proper temperature, then turn on the oxygen and wash off the head. The remaining portion of the rivet can then be punched out with a light hammer blow. The step-by-step procedure follows:

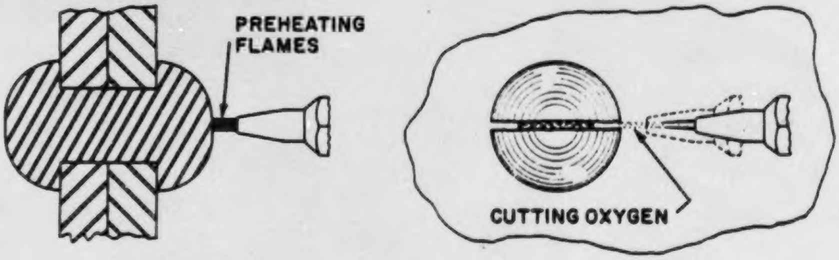
1. Use the size of tip and the oxygen pressure required for the size and type of rivet you are going to cut.

2. Heat a spot on the rivet head until it is bright red.

3. Move the tip to a position parallel with the surface of the plate and slowly turn on the cutting oxygen.

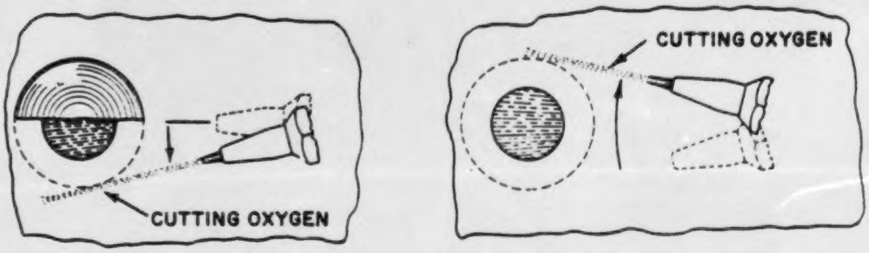
4. Cut a slot in the rivet head like the screwdriver slot in a roundhead screw. When the cut nears the plate, draw the nozzle back at least 1-1/2 inches from the rivet so that you will not cut through the plate.

5. When you have cut the slot through to the plate, swing the tip through a small arc. This slices off half the rivet head.



PREHEATING

SLOT CUT IN HEAD AS NOZZLE IS DRAWN 1½ INCHES AWAY



HALF OF HEAD SLICED OFF

REMAINDER OF HEAD CUT AWAY

11.134X

Figure 9-12.—Using the cutting torch to remove head of rivet.

6. Then swing the tip in an arc in the other direction to slice off the other half of the rivet head.

By the time the slot has been cut, the rest of the rivet head has usually been heated to cutting temperature. Just before you get through the slot, draw the torch tip back 1-1/2 inches to allow the cutting oxygen to scatter slightly. This keeps the torch from breaking through the layer of scale that is always present between the rivet head and the plate. It allows the head of the rivet to be cut off without damaging the surface of the plate. If you do not draw the tip away, you may cut through the film of scale and into the plate.

A low-velocity cutting tip is best for cutting buttonhead rivets and for removing countersunk rivets. A low-velocity cutting tip has a cutting oxygen orifice with a large diameter. Above this orifice are three heating orifices. Always place a low-velocity cutting tip in the torch so that the heating orifices are above the cutting orifice when the torch is held in the rivet cutting position.

To remove countersunk rivets from vertical sheet or plate, use the method shown in figure 9-13 and follow these instructions:

1. Hold the torch horizontally and turn it so that the tip also points horizontally.
2. Tilt the tip upward about 15° and hold the preheating flames on a point slightly below the center of the rivet head.
3. When you get the area heated to a dull red, move the torch upward, still keeping the upward tilt, and slowly open the cutting oxygen valve.
4. Hold the torch steady with the cutting stream directed at the center of the rivet. As the rivet is cut away, the angle of the torch should be decreased until the tip is perpendicular to the sheet or plate and the cutting stream is directed at the center of the rivet.
5. When you have cut through the head to the shank of the rivet, wash away the remainder of the head with one circular wiping motion. Always move the torch so that the cutting stream will follow the preheat.
6. The shank may then be removed with a hammer and punch.

Buttonhead rivets may be removed in the same manner as countersunk rivets with the low-velocity cutting tip. The process is illustrated step by step in figure 9-14. Remember that it is important to start below the center of the rivet head so that molten metal and slag will not be deposited on the plate.

CUTTING WIRE ROPE

The cutting torch is sometimes used to cut wire rope. Wire rope is made up of many strands. Since these strands do not form one solid piece of metal, you may encounter difficulty in making the cut. To prevent unlaying, the wire rope should be seized on each side of where the cut will be made. Instructions for seizing wire rope may be found in chapter 15 of this training manual. To cut wire rop with the torch, adjust the torch to give a neutral flame and cut between the seizings. If the wire rope is going to go through sheaves, then it would be desirable to fuse the wires together and point the end. This

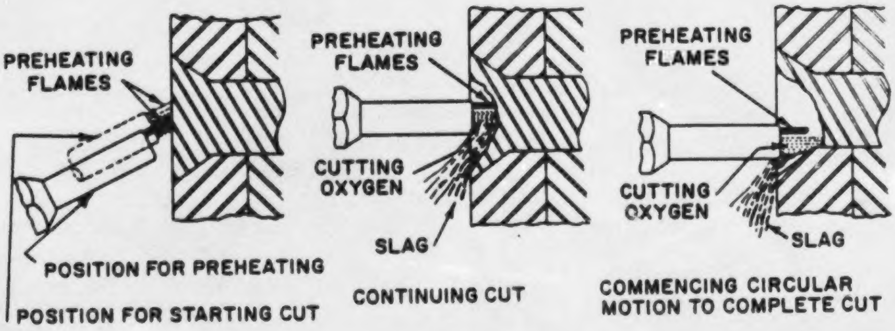


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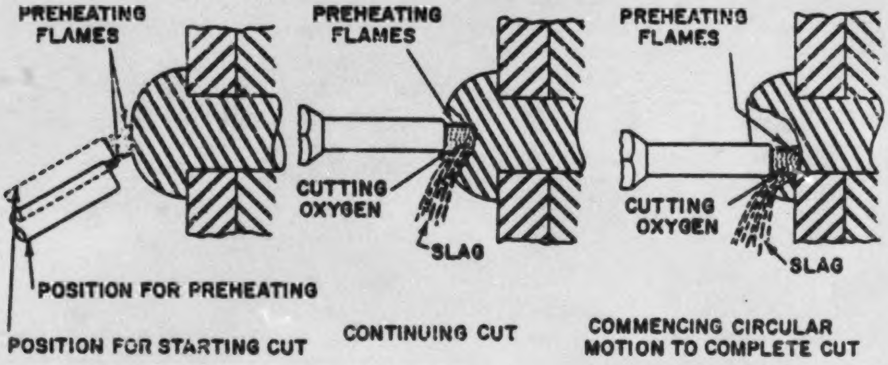
Figure 9-13.—Cutting a countersunk rivet with a low-velocity cutting tip.



11.136X
Figure 9-14.—Cutting buttonhead rivets with low-velocity cutting tip.

will make entrance into the block much easier, especially when you are working with a large size of wire rope, and when reeving blocks that are close together. In fusing and pointing wire rope, adjust the torch to give a neutral flame; then close the oxygen valve until you obtain a carburizing flame. With proper torch manipulation you can then fuse the wires together and point the wire rope at the same time.

Wire rope is lubricated during fabrication and is frequently lubricated again during its service life. Be sure that all excess lubricant is wiped off the wire rope before you begin to cut it with the oxyacetylene torch.

SPECIAL OXYACETYLENE CUTTING TECHNIQUES

Carbon steels containing up to 1.0 percent carbon are easily cut with the oxyacetylene cutting torch. Nonferrous metals, however, and ferrous metals such as cast iron, carbon steels containing more than 1.00 percent carbon, and many alloy steels can be successfully flame cut only if special techniques are used. These special techniques include using more intense and more widely distributed preheat; using different flame adjustments; introducing iron or low carbon steel into the cutting area; varying the torch movements; and using fluxes.

PREHEAT

Preheating the metal before cutting reduces the amount of oxygen and fuel gas required to make the cut. It also tends to prevent or minimize distortion and to prevent surface hardness of the piece after the cut has been made. While preheating is helpful in any cutting operation, it is essential for some of the metals and alloys which are not easily cut. The preheating temperatures generally used for oxyacetylene cutting range from 500° to about 600° F, although considerably higher temperatures are occasionally used.

Preheating is usually accomplished by using the preheating orifices in the cutting tip. Special tips having larger and more numerous preheating orifices are available for cutting cast iron and other materials which require intense and widely distributed preheat.

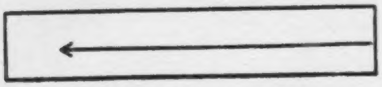
FLAME ADJUSTMENT

A neutral preheating flame is used for most oxyacetylene cutting. In some cases, however, other flame adjustments give better results. For example, a highly carburizing flame is used for preheating cast iron. The excess acetylene in the carburizing flame ignites when it combines with the cutting oxygen deep in the kerf, thus increasing both the intensity and the distribution of the preheat. For cutting cast iron, the length of the feather on the preheating flame should be approximately equal to the thickness of the cast iron. A slightly less carburizing flame is used for cutting stainless steels.

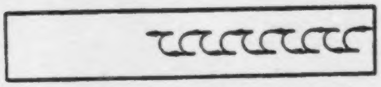
INTRODUCTION OF IRON OR LOW CARBON STEEL

Introducing iron or low carbon steel into the cutting area greatly simplifies the cutting of some metals. When the oxides of a metal have a higher melting point than the metal itself, the oxides protect the base metal from the cutting action of the oxygen; in such cases, introducing iron or low carbon steel into the cutting area solves the problem because the rapid oxidation of the iron or steel liberates enough heat to melt the oxides which would otherwise interfere with the cutting. When alloying elements are responsible for the difficulty in cutting the metal, the introduction of iron or low carbon steel reduces the percentage of these alloying elements and so makes the metal easier to cut.

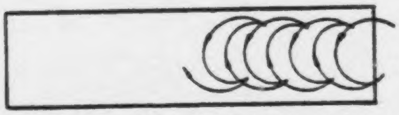
Several techniques are used to introduce iron or low carbon steel into the cutting area. An easily cut steel waster plate may be clamped firmly to the surface of the metal to be cut; a steel welding rod may be fed into the kerf as the cutting proceeds; a bead of low carbon steel may be deposited along the line of cut before the cut is made; or finely divided iron powder may be blown into the stream of cutting oxygen through special orifices in the cutting tip.



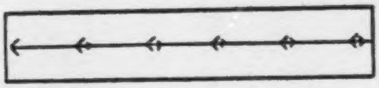
A. TORCH MOVEMENT FOR CUTTING LOW CARBON STEEL



B. TORCH MOVEMENT FOR CUTTING THIN SECTIONS OF CAST IRON



C. TORCH MOVEMENT FOR CUTTING HEAVY SECTIONS OF CAST IRON



D. TORCH MOVEMENT FOR CUTTING STAINLESS STEELS

11.137

Figure 9-15.—Manipulation of oxyacetylene cutting torch.

Cast iron, chromium irons, stainless steels, and various alloys having small ferrous content can be successfully cut with the oxyacetylene torch when iron or low carbon steel is introduced into the cutting area.

TORCH MOVEMENTS

For most oxyacetylene cutting, the torch is moved steadily forward along the line of cut, as shown in part A of figure 9-15. Metals that are difficult to cut often require special torch movements. For example, the oscillating movement shown in part B of figure 9-15 is suitable for cutting thin sections of cast iron; part C shows the oscillating movement that is best for cutting heavier sections of cast iron. Part D shows the reciprocating (or back and forth) torch movement that is most effective for cutting stainless steels.

FLUXES

Although fluxes are not used for most oxyacetylene cutting, they are used for cutting stainless steels, chromium irons, and other metals that are hard to cut. Fluxes used for cutting are nonmetallic compounds in powdered form. As the powdered flux is injected into the kerf, it reacts chemically with the oxides which have a higher melting point than the base metal. The result of this chemical reaction is a slag which melts at a lower temperature. The stream of cutting oxygen washes the molten slag out of the cut and exposes the base metal to the cutting action of the oxygen.

JUDGING THE QUALITY OF OXYACETYLENE CUTS

In order to know how good a job of cutting you are doing, you must know what constitutes a good oxyacetylene cut. In general, the quality of an oxyacetylene cut is judged by (1) the shape and length of the drag lines; (2) the smoothness of the sides; (3) the sharpness of the top edges; and (4) the amount of slag adhering to the metal.

DRAG LINES. Drag lines are the line markings which show on the cut surfaces. Good drag lines are almost straight up and down, as shown in part A of figure 9-16. Poor drag lines are long and irregular or excessively curved, as shown in part B of figure 9-16;

drag lines of this type indicate poor cutting procedure which may also result in loss of the cut (parts B and C of fig. 9-16). Drag lines are probably the best single indication of the quality of an oxyacetylene cut; if the drag lines are short and almost vertical, the smoothness of the sides, the sharpness of the top edges, and the slag conditions are almost sure to be satisfactory.

SMOOTHNESS OF SIDES. A satisfactory oxyacetylene cut shows smooth sides. A grooved, fluted, or ragged cut surface indicates a cut of poor quality.

SHARPNESS OF TOP EDGES. The top edges resulting from an oxyacetylene cut should be sharp and square (part D, fig. 9-16). Rounded top edges such as those shown in part E of figure 9-16 are not considered satisfactory. Melting down of the top edges may result from incorrect preheating procedures or from moving the torch too slowly.

SLAG CONDITIONS. An oxyacetylene cut is not considered satisfactory if slag adheres so tightly to the metal that it is difficult to remove.

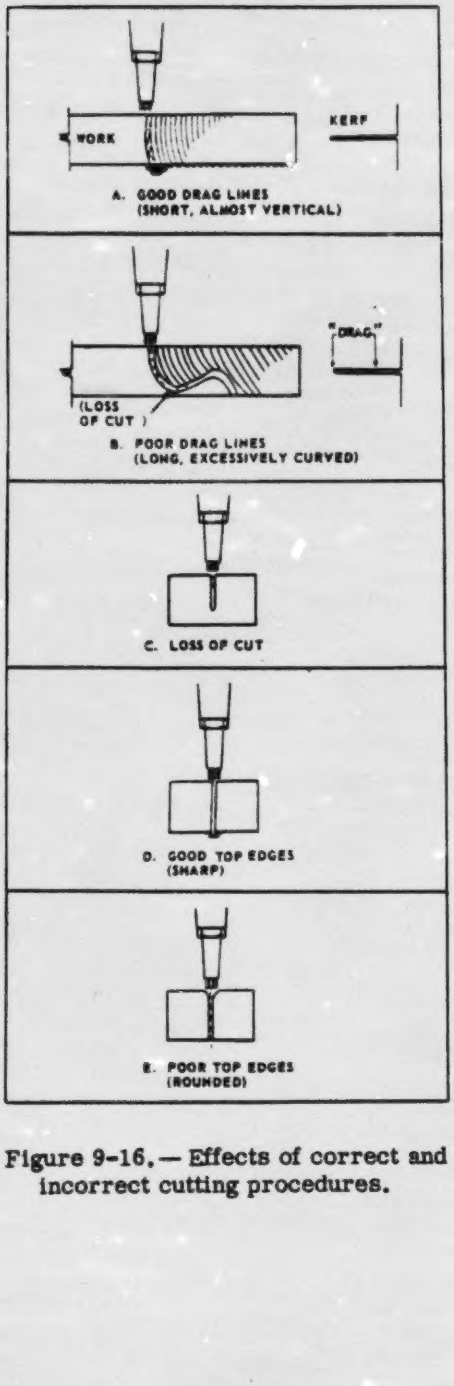


Figure 9-16.—Effects of correct and incorrect cutting procedures.

SAFETY PRECAUTIONS

In all cutting operations, be careful to see that hot slag does not come in contact with any combustible material. Globules of hot slag can roll along a deck for quite a distance. Do not cut within 30 or 40 feet of unprotected combustible materials. If combustible materials cannot be removed, cover them with sheet metal or asbestos guards. Keep the acetylene and oxygen cylinders far enough away from the work so that hot slag will not fall on the cylinders or hoses.

Many of the safety precautions discussed in chapters 7 and 8 of this training manual apply to cutting as well as to welding. As part of this instruction, it is suggested that you go back and review the material on safety in those two chapters. It is also suggested that you review the section entitled "Fire Prevention" in chapter 8. Be sure that you are entirely familiar with all appropriate safety precautions before attempting any oxyacetylene cutting operation.

CHAPTER 10

MISCELLANEOUS USES OF THE OXYACETYLENE FLAME

You are probably aware by now that there are many uses of the oxyacetylene flame. As a Steelworker, however, you will be concerned in particular with the following six oxyacetylene processes: torch brazing, braze welding, hardfacing, spot heating, oxyacetylene welding, and oxyacetylene cutting. Here we will discuss the first four of these processes. Oxyacetylene welding and cutting are discussed elsewhere in this manual. Except for minor modifications, the processes employ essentially the same equipment.

TORCH BRAZING

In the master chart of welding processes (fig. 7-1), you will note that brazing is one of the basic welding processes and that it includes a number of subsidiary processes. The Steelworker is primarily concerned with only one of the subsidiary brazing processes — namely, TORCH BRAZING. For that reason, torch brazing is the only brazing process described in this chapter.

Torch brazing is a brazing process wherein coalescence is produced by heating with a gas flame and by using a nonferrous filler metal having a melting point above 800° F, but below the melting point of the base metal. The filler metal is distributed in the joint by capillary attraction. The process of torch brazing, as its name indicates, requires the use of a torch (or torches) to apply the brazing heat.

In steelwork, torch brazing, sometimes called silver brazing, provides one of the most effective methods available for joining metals. This process is used to make joints in both ferrous and non-ferrous piping. It also is used in making repairs to machine parts, refrigeration equipment, water systems. Joints in dissimilar metals can be made by torch brazing. In addition, this process is suitable for making joints in electrical fittings and sheet metal objects.

Torch brazing and oxyacetylene welding are similar in a number of ways. A main difference between these two processes, however, is in the amount of heat used. In torch brazing only the filler metal (not the base metal) is melted, while in oxyacetylene welding the base metal, as well as the filler metal, is melted. Remember that brazing is the only welding process in which melting the base metal is not necessary for coalescence to occur. If the base metal does melt in brazing, it is because the operator is unable to control the application of heat.

CAPILLARY ATTRACTION

Since capillary attraction is important in the torch brazing process, it will be helpful to understand what is meant by this term. Perhaps the best way to understand capillary attraction is to consider some everyday examples of the process. If you put one end of a strip of cloth in a glass of water and allow the other end to hang over the edge of the glass, the end of the cloth which is not in the water will become wet. Water rises in the cloth by capillary attraction. When you use a blotter, the ink is drawn up into the blotter by capillary attraction. The wick on an oil lamp can be lit because the oil rises in the wick by capillary attraction. In each of these examples, we have a LIQUID (water, ink, oil) which moves into an opening in a SOLID (cloth, blotter, wick) by the process called capillary attraction. A basic rule of capillary attraction is that the distance the liquid will be drawn into the opening in the solid depends on the size of the opening in the solid; the smaller the opening, the farther the liquid will be drawn in.

In just the same way, capillary attraction causes the melted filler metal used in torch brazing to be drawn into the narrow clearance between the joining members. Capillary attraction will not work unless the filler metal is MELTED and unless the size of the opening is quite small. Therefore, the application of

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heat and the use of a very small clearance between joining members are essential to the torch brazing process. The heat is necessary in order to melt the filler metal and to keep it molten; the small clearance is necessary to allow capillary attraction to draw the molten metal into the space between the joint members.

TORCHES

Successful torch brazing depends largely upon the operator's ability to control the application of heat by manipulating the torch. Torches are provided with various sizes of tips, since one tip size cannot be used for making joints on all thicknesses of metal. A welding torch with welding tips is furnished in the Gas Cutting Welding Kit in the Organic Allowance Kit # 7013. (See figs. 10-1 and 10-2.) The torch is a versatile tool; besides its use for welding the torch has a cutting attachment and tips for cutting steel plate up to 6 inches thick. The torch is lightweight and well balanced. The size of tip selected for the torch should be determined by the type of work to be done. Table 10-1 may be used as a general guide in the selection of tip sizes.

Control of heat is the most difficult part of torch brazing, and can be done properly only if you know how to manipulate the torch.

Torch manipulation is something you cannot learn from a book. Ask your leading petty officer to show you the correct technique of torch manipulation, and then practice until you are able to handle the torch properly and efficiently.

BRAZING FILLER METALS

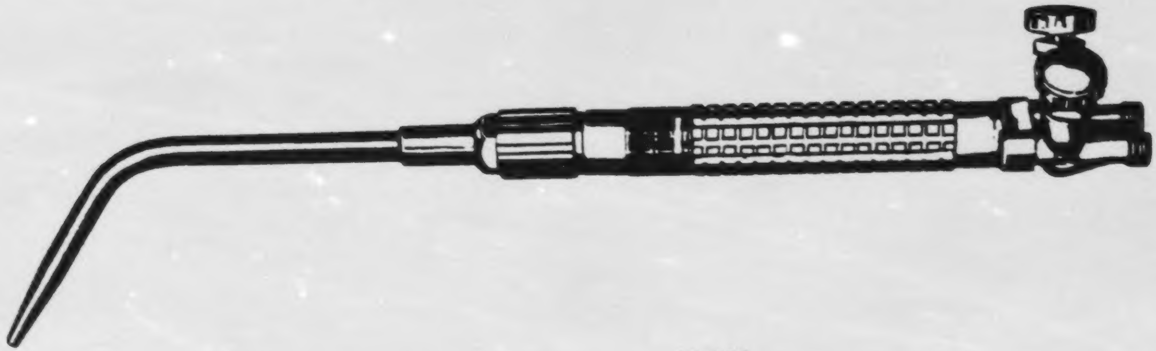
Brazing filler metals are nonferrous metals or alloys which have a melting temperature above 800°F but below the melting point of the base metal being joined. You may have heard these brazing filler metals referred to as silver solder, hard solder, or brazing alloys, but these terms are being replaced by the term BRAZING FILLER METAL. The American Welding Society (AWS) defines a brazing filler metal as a metal or alloy to be added in making a braze.

Brazing filler metals covered in Navy Specifications possess certain characteristics. Some of the major characteristics are:

1. They have a low melting point.
2. They have high tensile strength.
3. They are highly resistant to corrosion.
4. They flow readily at the lower brazing temperatures.
5. They braze readily to copper and to copper alloys.

There are a number of different brazing filler metals available. The metals commonly used for brazing filler metals include silver, copper, zinc, phosphorus, cadmium, and nickel; the percentage of the various metals included in any brazing filler metal determines the color, strength, melting point, and flow point of the brazing filler metal.

Table 10-2 lists the brazing filler metals commonly used in the Navy. There are eight different filler metals—grades O, I, II, III, IV, V, copper-phosphorus, and copper-zinc. Grades



11.126
Figure 10-1.—Welding torch.

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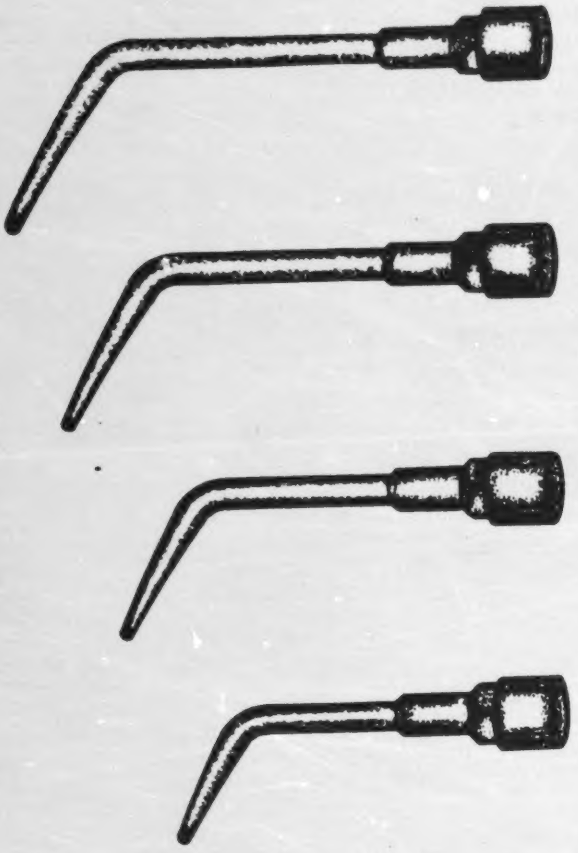


11.127
Figure 10-2.—Welding tips.

127.161
Table 10-1.—Tip sizes

Tip Size (Drill Rod Gage No.)	Tip Hole Dia. Ins.	Welding Range-ins. Steel Plate Thickness
68	.031	Up to 1/16
62	.038	1/16 - 1/8
54	.055	1/8 - 1/4
44	.086	1/4 - 1/2
36	.1065	1/2 - 3/4
30	.1285	3/4 - 1 1/4

O through V are referred to as silverbase brazing filler metals.

Grades O, I, and II are suitable for joining ferrous metals. These grades are relatively low in cost, but have limited use in the field.

Grade III is intended only for brazing copper and copper-base alloys. It is not intended for use with ferrous metals.

Grade IV is used for joining ferrous and nonferrous metals except those having melting points lower than the filler metal. For example, it should not be used on aluminum or zinc alloys. It should be used only where proper tolerances can be maintained.

Grade V is used when the characteristics of Grade IV are required but where close tolerances cannot be maintained or when the addition of a fillet is desired. Grade V should be used for brazing hard materials; for example, it should be used to braze carbide tool tips to steel shanks.

Copper-phosphorus filler metal is a higher melting point substitute for Grade III brazing filler metal. It is intended only for brazing copper and copper-base alloys, and should NOT be used on ferrous metals.

Copper-zinc filler metal has a higher melting point than copper-phosphorus filler metal, and is intended for brazing steels. However, 18-8 stainless steel and any steel that is to be heat treated should NOT be brazed with copper-zinc filler metal.

FLUXES

All brazing operations require the use of a flux. The flux acts to prevent the oxidation of the metal surfaces and to remove oxides already present. Flux also increases the flow of the brazing filler metal and increases its ability to adhere to the base metal. It brings the brazing filler metal into immediate contact with the metals being joined, and permits the filler to penetrate the pores of the metal, thus forming a strong joint.

The fluxes used in the Navy are selected in accordance with specifications, so as to meet the requirements of brazing with silver-base, copper-base, or nickel-base alloys. For best results, a flux must become active at a temperature slightly below the melting point of the filler metal, and must remain fluid at the brazing temperature. Regardless of the type of flux you select, it is most important that you apply it in such a manner that all oxide film is removed.

11.386

Table 10-2.—Brazing Filler Metals Commonly Used in the Navy

Brazing filler metal	Grade No.	Composition (%)	Melting and flow point[1]	Shape	Color	Suggested use
Copper-silver	0[2]	Silver . . . . 20 Copper . . . 45 Zinc 35	1430° F 1500° F	Strip	Yellow . .	Sealing joints operating up to 1230° F. Suitable for joining ferrous metals.
Copper-silver	I[2]	Silver . . . . 45 Copper . . . 30 Zinc 25	1250° F 1370° F	Strip or wire.	Nearly white.	Sealing joints operating up to 1050° F. Suitable for joining ferrous metals.
Copper-silver	II[2]	Silver . . . . 65 Copper . . . 20 Zinc 15	1280° F 1325° F	Strip	White. . .	High silver content primarily for color match. Suitable for joining ferrous metals.
Copper-silver	III	Silver . . . . 15 Copper . . . 80 Phosphorus 5	1200° F 1300° F	Strip or wire.	Gray-white.	For brazing copper and copper-base alloys.
Copper-silver	IV	Silver . . . . 50 Copper . . . 15 Zinc . . . . . 17 Cadmium . . 18	1160° F 1175° F	Strip or wire.	Yellow-white.	For brazing all ferrous and nonferrous metals except those having lower melting points. Use only where proper tolerances can be maintained.
Copper-silver	V	Silver . . . . 50 Copper . . . 15 Zinc . . . . . 15 Cadmium . . 17 Nickel 3	1195° F 1270° F	Strip or wire.	Yellow-white.	For same applications as Grade IV but where close tolerances cannot be maintained. For brazing hard metals.
Copper-phosphorus	---	Copper . . . 93 Phosphorus 7	1300° F 1382° F	Strip or wire	Gray-red	For brazing copper and copper-base alloys; do not use on ferrous metals.
Copper-zinc	---	Copper . . . 50 Zinc 50	1600° F	Wire	Yellow	Brazing steel except 18-8 stainless and steels to be heat treated.

[1] In all instances, the lesser temperature indicates melting point and the higher temperature indicates flow point of the brazing filler metal.

[2] Grades 0, I, and II have limited use in the field.

Flux may be obtained in three forms: liquid, paste, and powder. When used either in paste form or in liquid form, the flux is applied with a brush to both parts of the joint; best results are obtained when the filler metal also is given a coat. Use a circular motion in brushing it on, and let the flux extend outside the joint or fitting. Brushing the flux on with a circular motion gives a uniform coating and lessens the possibility of bare spots that will oxidize during heating. When used in powdered form, the filler rod can be heated and dipped into the powdered flux.

Borax or a mixture of borax and other chemicals is most often used as a flux. Up to a certain point heat causes borax to swell and bubble. Common crystalline borax, although it appears perfectly dry, contains approximately 47 percent water of crystallization (water which is chemically combined in a crystallized substance). When the borax is heated this water is driven off, causing the borax to appear to boil. Borax may be mixed with water to form a paste, but because of the ability of borax to hold water, it will quickly take up the water and become crystalline borax again. If commercial powdered borax is used, see that it is kept in sealed glass jars.

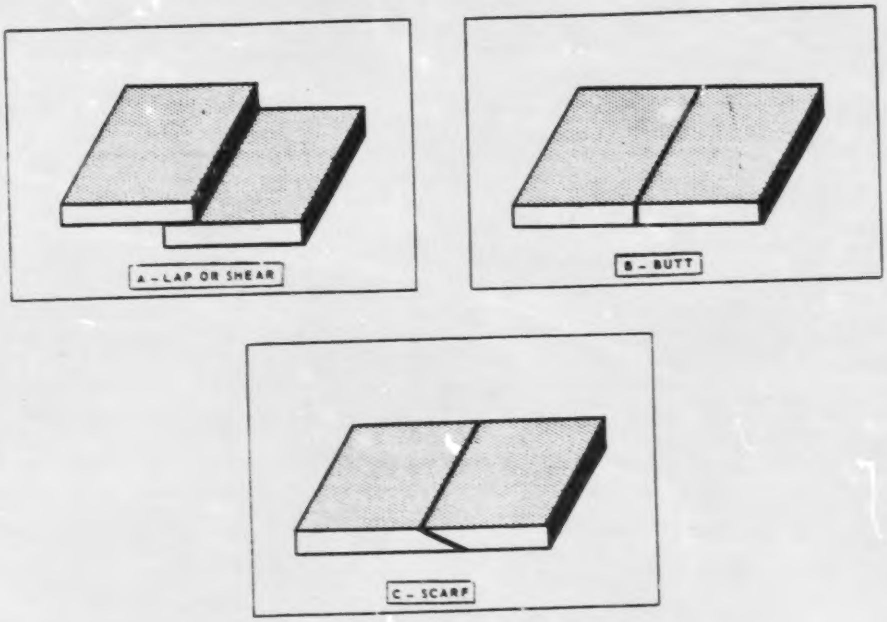
If a prepared flux is not available, a mixture of 12 parts of borax and 1 part boric acid may be used as a flux for brazing.

When applying flux or assembling the parts, avoid handling the polished parts of the joint or you will defeat the purpose of cleaning. If the coating of liquid or paste flux dries before the parts are assembled, a fresh coating of flux should be applied. Flux should always be applied as soon as a joint area is cleaned, even though it will not be brazed immediately. After the brazing is completed, wash with warm water to clean away all the residue left by the flux.

Nearly all fluxes give off fumes that may be toxic. Thus, fluxes should always be used in WELL-VENTILATED spaces.

TYPES OF JOINTS

Since the filler metal used in brazing must be distributed by capillary action, the joints must be of a type that requires closeness of fit. In brazing there are three basic joint designs (fig. 10-3): lap, butt, and scarf. The joint members in which these designs are used may be flat, round, tubular or irregular in cross section.



11.116

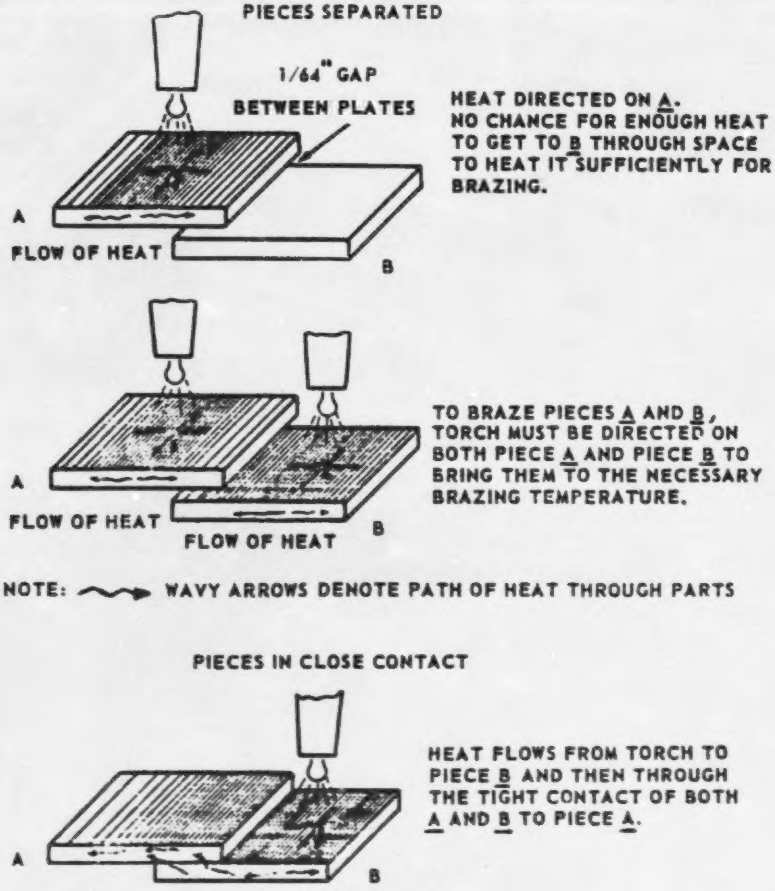
Figure 10-3.—Joint designs for brazing.

The lap (or shear) joint design is used most frequently in brazing, especially in pipework. Good practice requires a length of lap at least three times the thickness of the metal being joined. A 0.001-inch to 0.003-inch clearance between the members of the joint provides the greatest strength with silver-base brazing filler metals.

High strength butt joints can be made if a joint clearance between 0.001 and 0.003 inch can be maintained in the finished braze. The edges of the joint must be perfectly square so that a uniform clearance exists between all portions of the joint surfaces. Butt joints are usually used where the double thickness of a lap joint is undesirable. When double metal thickness is objectionable, the scarf joint is probably better.

A scarf joint provides an increased area of bond without increasing the thickness of the joint. The area of bond, however, depends on the angle at which the edges of the joint are scarfed. Usually, an area of bond two to three times that of a butt joint in the same thickness of material is desirable. A scarf angle of 30° gives a bond area twice that of a 90° butt joint and a scarf angle of 19 1/2° gives a bond area three times that of a butt joint.

Many modifications of these basic joint designs are employed. In some instances, the brazing filler metal is added when the proper temperature has been attained. In other instances, the filler metal is preplaced in the joint before heat is applied. This technique is



HEAT DIRECTED ON A. NO CHANCE FOR ENOUGH HEAT TO GET TO B THROUGH SPACE TO HEAT IT SUFFICIENTLY FOR BRAZING.

TO BRAZE PIECES A AND B, TORCH MUST BE DIRECTED ON BOTH PIECE A AND PIECE B TO BRING THEM TO THE NECESSARY BRAZING TEMPERATURE.

NOTE: WAVY ARROWS DENOTE PATH OF HEAT THROUGH PARTS

HEAT FLOWS FROM TORCH TO PIECE B AND THEN THROUGH THE TIGHT CONTACT OF BOTH A AND B TO PIECE A.

11.118

Figure 10-4.—Flow of heat.

common in pipework where special fittings containing pre-inserted rings of brazing filler metal are employed. The technique is also used in sheet metal work involving locked seams. Here the brazing filler metal is placed in the seam before it is locked. The pre-placed insert method produces a strong leak-tight joint in both sheet metal and pipework.

HEAT FLOW

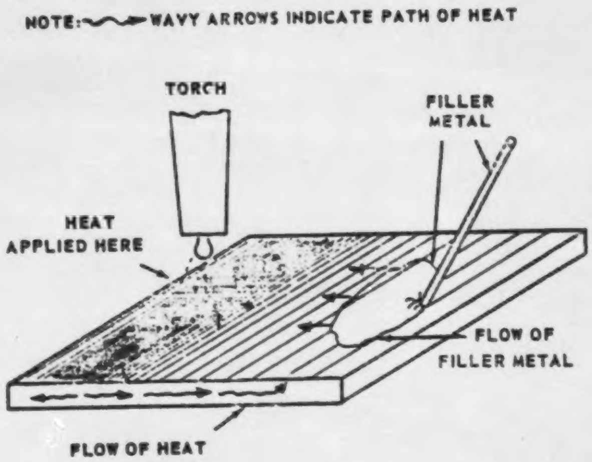
Some knowledge of the principles of heat flow through metals is necessary for an understanding of brazing techniques. The following discussion will brief you on some of the important factors concerning the flow of heat in metals.

Heat always flows from a hotter area to a colder area. The process by which heat flows from molecule to molecule through a metal is called CONDUCTION. Conduction takes place quite rapidly in most metals, but air is a very poor conductor of heat. Therefore, it two pieces of metal that are to be joined by brazing are not in contact with each other, each piece must be heated separately. If the two pieces are in contact with each other, you can heat them both by applying heat to one of them; the second piece will be heated by conduction from the first piece. These principles are illustrated in figure 10-4.

In the molten state, filler metal flows from the colder towards the hotter areas on a heated surface. Thus, you might say that the filler metal flows in a direction OPPOSITE to the direction of flow of the heat. This principle is illustrated in figure 10-5.

The brazing filler metal and the flux used in brazing cannot occupy the same space at the same time. Therefore, a clearance must be provided in the setup of the joint so that the filler metal can flow in and the flux can flow out. Heat should be applied in the manner shown in figure 10-6 so that the flux will flow out when the filler metal reaches the bonding temperature.

Heat travels faster through some metals than through others (fig. 10-7). Although all metals and alloys have high conductivity as compared with most other substances, there is a good deal of variation in the speed with which various metals and alloys will conduct heat. Copper, for example, is a very rapid conductor of heat. When two pieces of different metals are to be joined by brazing, the difference in heat conductivity of the two metals causes some problems in heating. For example, if you are trying to join a steel part and a copper part by brazing, you will find that the steel part reaches the joining temperature more rapidly and has a tendency to overheat because the heat is carried away from it more slowly. The copper part, on the other hand, conducts heat away from the brazing area more rapidly than the steel part does. Therefore, more heat is required to bring the copper part to the brazing temperature.



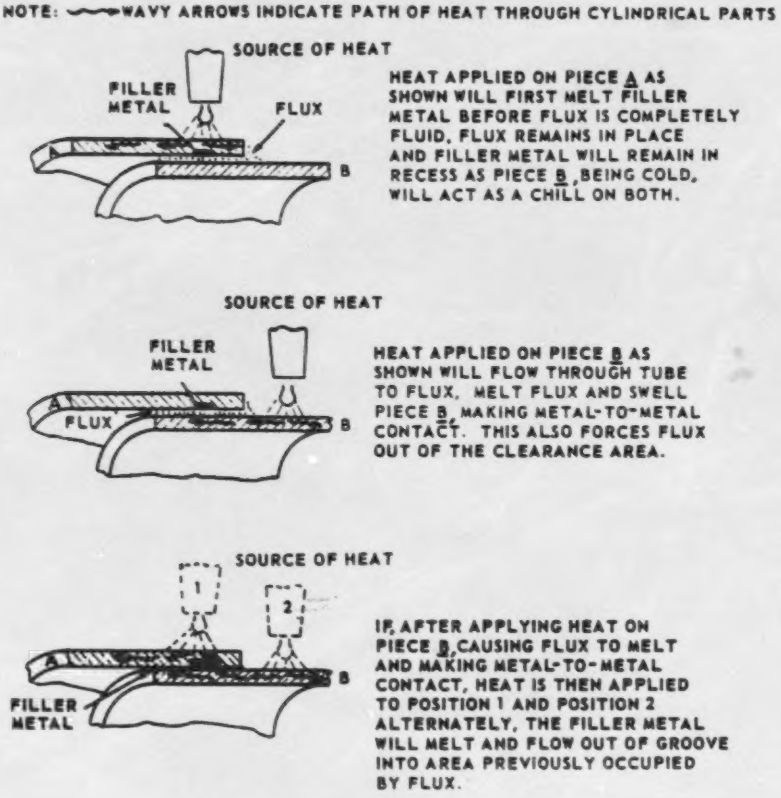
11.119

Figure 10-5. — Flow of molten filler metal.

As you can see, control of heat is one of the most difficult parts of brazing. In order to control heat properly, you must learn to manipulate the torch correctly and you must remember the points just discussed concerning the flow of heat through metals. Basically, the problem of heat control in brazing is one of bringing BOTH parts to the correct temperature at the same time. If one piece is hot enough but the other is not, the filler metal will flow onto the hot piece but it will not bond to the cooler piece.

POINTERS ON TORCH BRAZING

To obtain satisfactory results in torch brazing, it is important that the metal be properly cleaned before starting to braze. The metal should be free from OIL, GREASE, OXIDES, DIRT, SCALE, and RUST. Oil or grease will tend to repel the flux and will leave bare spots that will oxidize under heat. Oil or grease also will carbonize under heat and will leave a film on the metal. Oxides are to be avoided because the alloys will not flow over, or bond to, them. Dirt,



HEAT APPLIED ON PIECE A AS SHOWN WILL FIRST MELT FILLER METAL BEFORE FLUX IS COMPLETELY FLUID. FLUX REMAINS IN PLACE AND FILLER METAL WILL REMAIN IN RECESS AS PIECE B, BEING COLD, WILL ACT AS A CHILL ON BOTH.

HEAT APPLIED ON PIECE B AS SHOWN WILL FLOW THROUGH TUBE TO FLUX, MELT FLUX AND SWELL PIECE B, MAKING METAL-TO-METAL CONTACT. THIS ALSO FORCES FLUX OUT OF THE CLEARANCE AREA.

IF, AFTER APPLYING HEAT ON PIECE B, CAUSING FLUX TO MELT AND MAKING METAL-TO-METAL CONTACT, HEAT IS THEN APPLIED TO POSITION 1 AND POSITION 2 ALTERNATELY, THE FILLER METAL WILL MELT AND FLOW OUT OF GROOVE INTO AREA PREVIOUSLY OCCUPIED BY FLUX.

11.120

Figure 10-6.—Flow of flux and filler metal.

scale, and rust must be removed in cleaning because the alloy will not bond to these materials. Proper application of the flux also will be prevented if the metal is not free of dirt, scale and rust. To clean the metal, use emery cloth or steel wool. Or, if you prefer, an accepted cleaning solvent—such as solutions of trichloroethylene or trisodium phosphate—may be used. Do not use sandpaper due to possible inclusion of silicon particles.

Parts to be brazed should be assembled on firebricks or some other suitable means of support. Jigs also will be needed frequently to hold the work in place. Supports and jigs should absorb as little heat as possible.

If you have heavy and thin metal sections to braze together, be careful to avoid overheating the thin part. A good example is the brazing of thin copper tubing to a heavy cast fitting. If the same amount of heat were applied to the tubing as to the casting, the tubing would be overheated and probably burned. Therefore, most of the heat must be directed toward the heavier part. Frequently, heavy parts and large areas must be preheated for best brazing results. Preheating may be done with a forge, furnace, oil burning torch, gasoline torch, or with a welding torch.

When applying heat with the oxyacetylene torch for brazing with a silver-base filler metal, use a neutral or slightly reducing flame. Select a torch tip to suit the type of work you are doing. Ordinarily a size 4, 5 or 6 tip is suitable for brazing bar stock. Keep the inner cone of the flame from 1/4 to 1/2 inch away from the metal. Play the flame over the surface with a circular, sweeping motion, so that you obtain uniform heating of the parts to be joined. The flame should be solf so that it will not blow or boil

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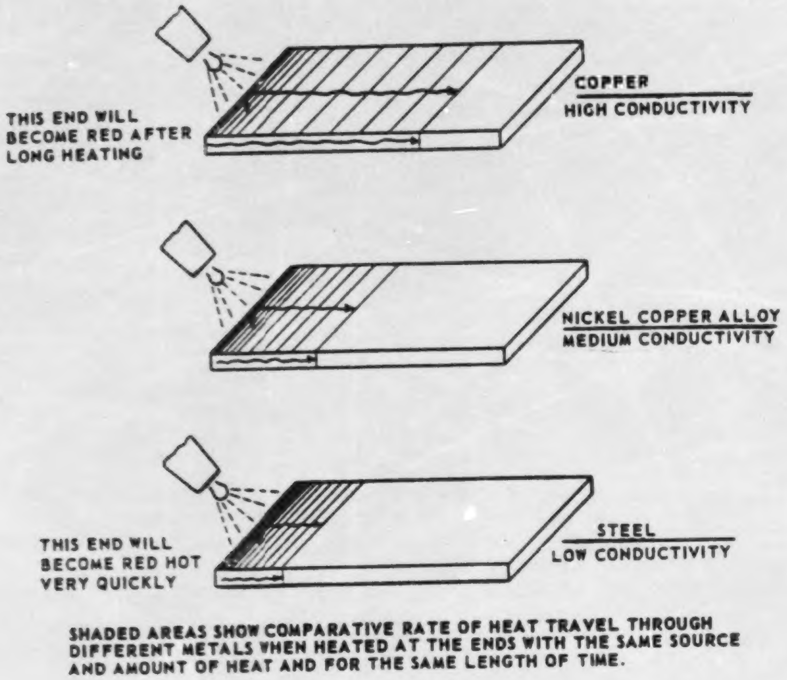

THIS END WILL BECOME RED AFTER LONG HEATING
COPPER
HIGH CONDUCTIVITY
NICKEL COPPER ALLOY
MEDIUM CONDUCTIVITY
THIS END WILL BECOME RED HOT VERY QUICKLY
STEEL
LOW CONDUCTIVITY
SHADED AREAS SHOW COMPARATIVE RATE OF HEAT TRAVEL THROUGH DIFFERENT METALS WHEN HEATED AT THE ENDS WITH THE SAME SOURCE AND AMOUNT OF HEAT AND FOR THE SAME LENGTH OF TIME.

11.121

Figure 10-7.—Relative rate of heat flow through copper, copper-nickel alloy, and steel.

the molten filler metal. If possible do all heating from the back side of the joint being brazed. This procedure will not burn the flux or melt the filler metal prematurely.

Bring up the temperature of the parts until the flux on them is melted. Continue heating the parts to be joined until they are hot enough to melt the filler rod. The filler should be melted by the heat of the joint, not by the flame. It should flow like water wherever the flux has been applied. Avoid overheating. Use just enough heat to get the parts of the joint hot enough to melt the filler metal so that it can flow.

The amount of flux used depends upon the heating time of the metals being brazed. Ordinarily, a thin layer of flux is used on soft oxides such as copper, while a heavy coating of flux is required on hard oxides such as stainless steels. The longer the heating time, the more flux required. It is suggested that you think of flux as a blotter, absorbing oxides in the same manner as a blotter absorbs ink. When the entire blotter is saturated, then you need another blotter, same as you need more flux when what you have becomes saturated with oxides.

With experience you will learn how to use flux as a guide for alloy placement and proper temperature. At various (approximate) temperatures, certain conditions can be expected in the flux, as indicated below.

At 212° F, the water boils off the flux.

At 600° F, the flux becomes white, slightly puffy and starts to work.

At 800° F, the flux has a milky appearance and lays against the surface.

At 1100° F, the flux is completely clear and active and has the appearance of water.

At 1600° F, the flux burns and turns black.

Slow and uniform cooling is essential for a good brazed joint. You can control the rate of cooling by postheating the joint; but if the whole joint is to cool at a uniform rate, the lightest or thinnest metal, which will naturally cool faster than the heavy sections, must receive most of the postheating.

AVOID placing any stress upon a brazed joint until it has cooled to below 500° F, since the filler metal has a low tensile strength at temperatures higher than this point. This is a reason for never attempting to hot-work a brazed joint, although it can be cold-worked and annealed without damage.

MAKING BRAZED JOINTS

Silver-base alloys are commonly used as filler metal for brazing. Although filler metals other than silver-base alloys are often employed, the technique for making a brazed joint is basically the same. A main difference is the amount of heat necessary to melt the filler metal, which in all instances is below the melting point of the base metals. Silver brazed joints have high strength on ferrous and nonferrous metals. The strength of a properly made joint will exceed that of the metals joined. On stainless steels it is possible to develop a joint tensile strength of approximately 130,000 psi. Since brazing with silver-base alloys is typical of brazing generally, we are especially interested here in the use of these materials as filler metal. What is said, though, applies equally to brazing with other filler metals that are distributed by capillary attraction.

Two methods are used to make joints between tubes and fittings in piping systems with silver-base brazing filler metal: the INSERT method, and the FEED-IN method. With either method, the parts must be adequately supported during heating. It is also important that the work be held firmly in position until the brazing filler metal has completely solidified.

When using the INSERT method, s strip of the silver-base filler metal is inserted in the joint prior to assembly. Before brazing the parts, clean them with emery cloth, steel wool, or an accepted cleaning solvent. Apply flux with a brush. Next, fit the two parts together and align them. Then light off the torch and direct the heat on the tube or thinner portion as shown in view A of figure 10-8. The lines drawn on the tube indicate the path of the torch while heating the tube.

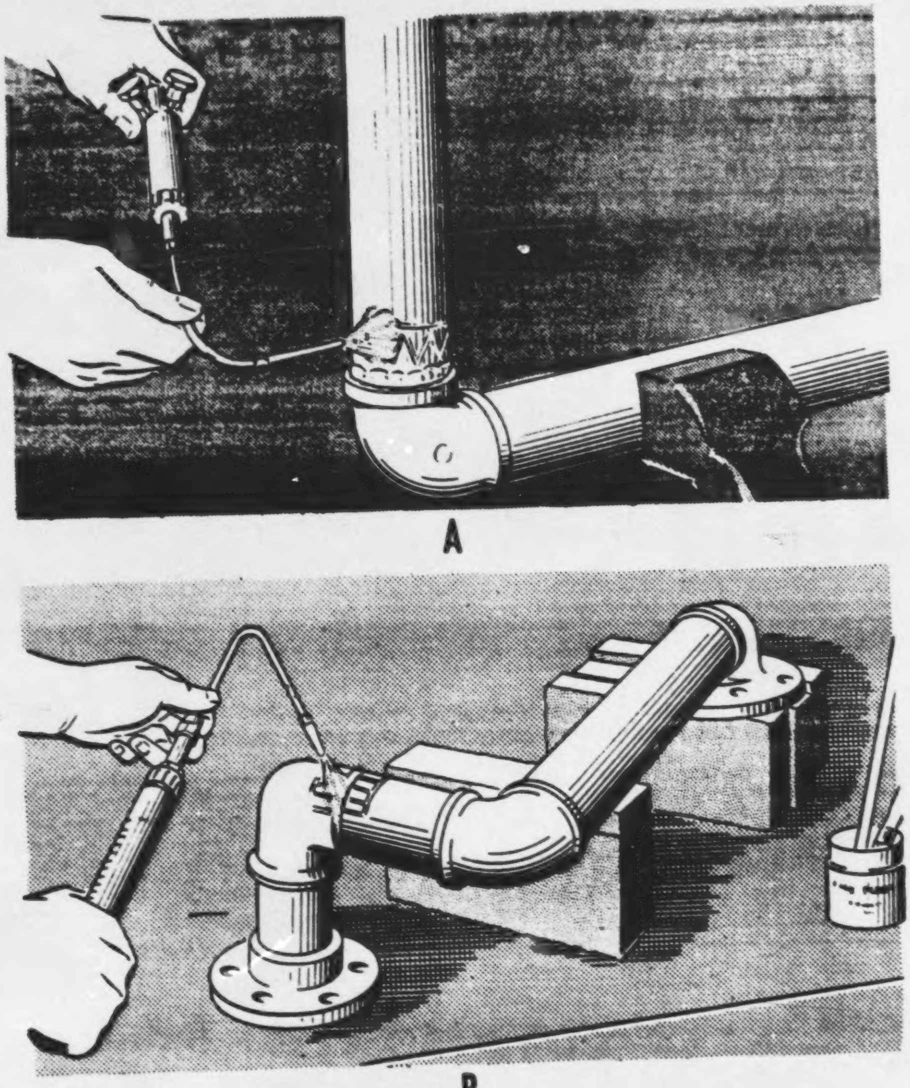
Heat applied to the tubing causes it to swell and bring the surface of the tube into contact with the inside surface of the fitting. This closes the clearance area, forcing the flux from either end of the joint. Be sure to heat the entire circumference of the tube until flux begins to flow. Flux flow tells you that the tube has expanded sufficiently and is the signal to proceed to the second phase of heating. As soon as the flux flows freely—about 6 seconds after fluidity becomes apparent—direct the flame to that portion of the fitting hub farthest from the junction of the tube and the fitting. Rotate the flame over the joint segment until brazing filler metal appears at the junction of the pipe and fitting. At that moment, flick the torch away so that the flame wipes toward the pipe. This completes one sigment of the joint. The procedure is repeated until all segments are completed. A satisfactory joint shows a continuous ring of filler metal at the end of the fitting. The ring must be smooth and concave.

In the insert method the filler metal will not leave the recess unless both parts are at the proper bonding temperature. If one of the parts is up to temperature and the other is not, the filler metal will not flow because it will be cooled or quenched by the surface not yet up to temperature. By playing the torch over a 2-inch or 3-inch section of the fitting you can cause the fitting to stretch or open up and let whatever remaining flux is present run out. Then hold the torch off the work and the fitting will return to normal size and force the filler metal to the edge of the fitting. You may be sure that a good joint is formed when you can see the filler metal at one or both edges of the joined area. Figure 10-9 shows the step-by-step process of brazing by the insert method.

The FEED-IN METHOD, sometimes called the STICK-FEED METHOD, is accomplished by feeding the filler metal by hand into the area to be joined. In this method, remember that the filler metal always flows along a heated surface from the cooler to the hotter section. In other words, the filler metal flows toward the source of heat or to the point where the heat is being applied. In this method, feed the filler metal to the outer edge of the joint while directing heat to the inner edge of the joint. Figure 10-10 illustrates the step-by-step technique for brazing a joint by the feed-in method.

The parts to be joined are cleaned and fluxed in the same manner as in the insert method. When the parts are fitted together the clearance area is filled with flux. After aligning the parts, in the case of a tube and fitting, heat the tube as previously described.

Heat is then applied to the fitting or the inner edge of the joint at the same time that the filler metal is fed at the outer edge of the joint. As the filler metal will flow toward the hottest section, it will flow through the joint toward the point at which the heat is being applied. In using this method you must determine when both parts are properly heated

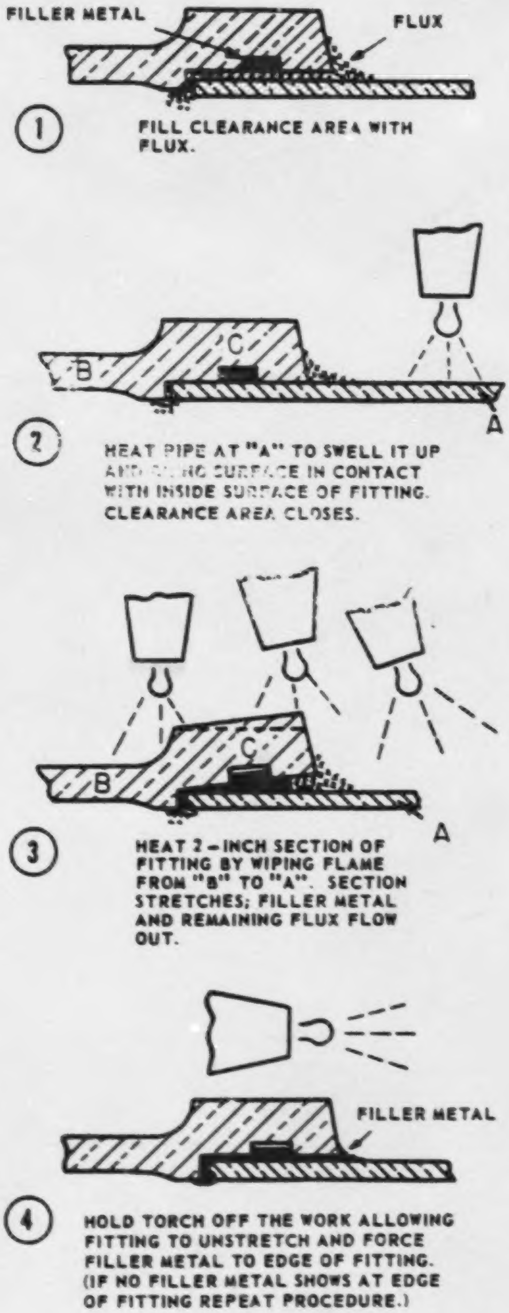


11.122

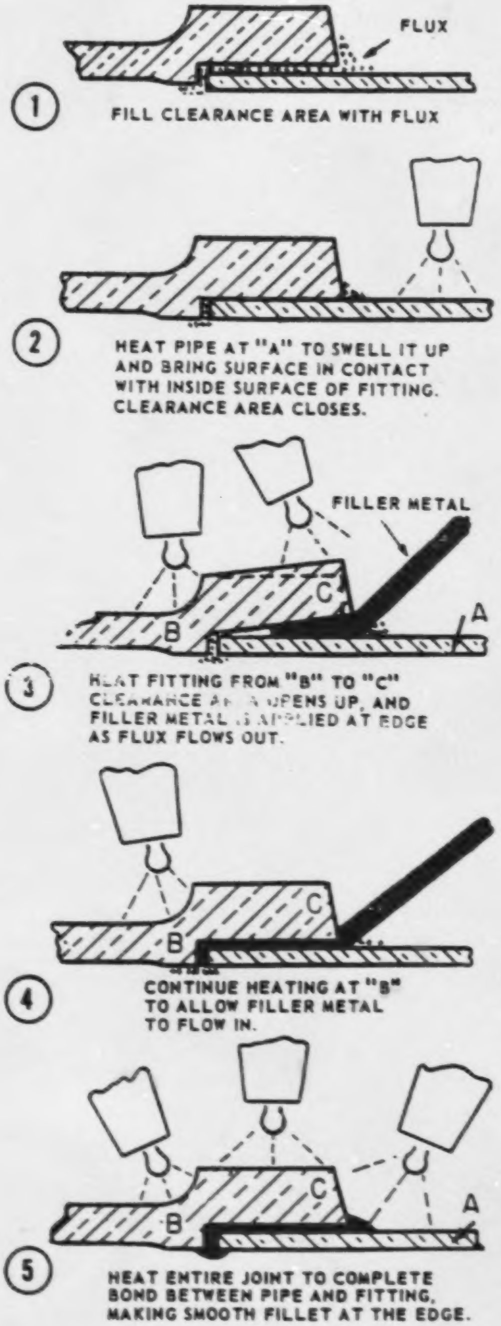
Figure 10-8.—Applying heat for brazing a tube and fitting.

and when to feed the filler metal. You must also determine when sufficient filler metal has been fed into the joint to completely fill the space between the two parts being joined. Skillful torch manipulation is necessary to apply heat to the proper point to cause the filler metal to flow from the cooler to the hotter section. In the feed-in method, filler metal visible at the edge of the joint does not necessarily indicate that the entire joint is filled.

The difference, then, between making a joint by the insert method and with the feed-in method is in procedure. When using the insert method, you heat a section and remove the torch with a wiping motion which causes the filler metal to flow from the insert. In the feed-in method, after you heat a section, the flame must be directed to the inside edge of the joint while the filler metal is being fed in at the outside edge of the fitting.


FILLER METAL
FLUX
①
FILL CLEARANCE AREA WITH FLUX.
B
C
A
②
HEAT PIPE AT "A" TO SWELL IT UP AND BRING SURFACE IN CONTACT WITH INSIDE SURFACE OF FITTING. CLEARANCE AREA CLOSES.
B
C
A
③
HEAT 2-INCH SECTION OF FITTING BY WIPING FLAME FROM "B" TO "A". SECTION STRETCHES; FILLER METAL AND REMAINING FLUX FLOW OUT.
FILLER METAL
④
HOLD TORCH OFF THE WORK ALLOWING FITTING TO UNSTRETCH AND FORCE FILLER METAL TO EDGE OF FITTING. (IF NO FILLER METAL SHOWS AT EDGE OF FITTING REPEAT PROCEDURE.)

11.123
Figure 10-9. — Insert method of brazing.


FLUX
①
FILL CLEARANCE AREA WITH FLUX
②
HEAT PIPE AT "A" TO SWELL IT UP AND BRING SURFACE IN CONTACT WITH INSIDE SURFACE OF FITTING. CLEARANCE AREA CLOSES.
FILLER METAL
B
C
A
③
HEAT FITTING FROM "B" TO "C" CLEARANCE AREA OPENS UP, AND FILLER METAL IS APPLIED AT EDGE AS FLUX FLOWS OUT.
B
C
④
CONTINUE HEATING AT "B" TO ALLOW FILLER METAL TO FLOW IN.
B
C
A
⑤
HEAT ENTIRE JOINT TO COMPLETE BOND BETWEEN PIPE AND FITTING, MAKING SMOOTH FILLET AT THE EDGE.

11.124
Figure 10-10. — Feed-in method of brazing.

After the joint has been completed and cooled, clean the joint area with a wire brush and warm water. This will remove flux, scale, and discoloration.

The description of the brazing techniques in the preceding paragraphs applies specifically to joints between tubes and fittings in piping systems. Except for minor differences, the procedure is the same when brazing sheet, strap, or bar stock. Here, though, the feed-in rather than the insert method is usually employed. Lap joints are used with material less than 1/8 inch thick, while scarf joints (see fig. 10-13) are usually employed when section thickness is greater than 1/8 inch. The following description points out the difference between pipe brazing and seam brazing.

SEAM BRAZING

Seam brazing requires some means for holding the parts in position. Short pieces can be clamped or riveted at the ends. Longer pieces are wired to size by using wire clamps. After wiring or clamping the parts in position, place additional flux along the outside of the seam. Then, tack weld both ends of the seam. Additional tack welds are made along the seam approximately 8 inches apart. To make a tack weld, direct the flame to both parts of the seam on a spot approximately 6 inches in diameter. As soon as the flux becomes liquid in this spot, direct the flame to the sheet forming the underneath part of the seam. Place a layer of brazing filler metal approximately 1 inch long on the edge of the seam. Now direct the flame to the sheet forming the upper part of the seam. This will draw the brazing filler metal through the joint, completing the tack weld. When all tacks are completed the seam is ready for brazing.

The seam is brazed in sections 4 or 5 inches in length. Start the braze about 2 inches away from the tack at the edge of the seam. Hold the torch so that the flame is pointed in the direction that brazing is to be accomplished, directing the flame first along one sheet and then along the other until the flux becomes liquid. When this occurs, direct the flame to the sheet forming the underneath part of the seam and, at the same time, deposit a layer of filler metal along the edge of the seam. Brazing filler metal is drawn into and through the joint by a wiping motion of the torch, forming the brazed joint in that section. Repeat this procedure continuously along the joint until the entire seam has been completed.

Remember that brazing filler metal flows along a sheet in the direction of the hottest point. This point is usually where the torch flame is being applied. Apply heat long enough to draw the filler metal through the seam. Care should be taken to avoid forming beads or globules along the inside edge of the seam.

DISASSEMBLING TORCH-BRAZED JOINTS

Repairs to or alterations of a piping system often involve the disassembly of torch-brazed joints. For operations of this kind, use a tip one or two sizes larger than that used for brazing a similar joint. The fitting or tube must be held securely in a fixed position before heat is applied. With the exception of the initial tube heating phase, the same rotary torch manipulation previously described for making the joint is employed for breaking the joint. Cover the joint with flux and use it to gage the temperature. Add a little new filler metal while heating. When the filler metal flows, pull the parts apart.

Fittings and valves are easily damaged by shock when they are hot. For that reason, handle them carefully and NEVER use a hammer to disassemble a joint. Tubes, pipes, and fittings removed from a system can be cleaned, resized, and used again if inspection reveals that they are in satisfactory condition. Reassembly is accomplished by the same method as that employed for new installations.

BRAZING SAFETY

Most brazing operations do not involve any special hazards not common to other welding processes. Except for special precautions to be observed in using certain brazing materials, normal ventilation is adequate for brazing operations.

Make sure you exercise care in handling hot objects. Steelworkers performing brazing operations must wear suitable clothing, including safety type shoes, which will provide protection against heat and falling objects. Welding goggles should also be worn. Information on protective clothing and welding goggles is given in chapter 7 of this manual. If necessary, go back to chapter 7 and review the section entitled "Safety" as part of this instruction.

It is recommended that you use plastic or rubber gloves or protective creams to keep the flux from getting to the skin or under fingernails. Some brazing filler metals contain toxic materials and some fluxes contain fluorides and other fluorine compounds. Therefore, special precautions in the use of such filler metals and fluxes without harmful effects must be observed.

BRAZE WELDING

The term BRAZE WELDING refers to the process of joining metals with an alloy of copper and zinc as the filler metal, or more exactly, the bonding agent. The joint designs used in braze welding are similar to those employed in oxyacetylene welding. In many instances, braze welding produces a joint stronger at the bond than the parent metal. You may also hear braze welding called BRAZING, as well as BRONZE WELDING.

Braze welding is similar in some ways to torch brazing. In both processes, a filler metal with a melting point lower than the base metal is used. Too, a nonferrous filler metal is used in both processes. Braze welding and torch brazing also are similar in that, in both processes, ONLY the filler metal is melted—not the base metal.

There are, of course, differences between torch brazing and braze welding. A main difference is that in torch brazing the filler metal is distributed into the joint by capillary attraction, while in braze welding the filler metal is distributed into the joint by a process of tinning. Closely related to this difference is the fact that different joint designs are used in the two processes.

In braze welding, the surface of the base metal is said to be TINNED when a very thin continuous film of filler metal precedes the main part of the filler metal, thus preparing the way for the main part of the filler metal.

Tinning can only occur on metal that has been cleaned, fluxed, and heated to the correct temperature. If tinning does not occur, the main part of the filler metal will not adhere to the base metal.

The fact that braze welds are made without melting the base metal greatly simplifies the welding procedure. Since braze welding requires less heat, the speed of welding is increased.

Because of the lower temperatures required for braze welding, preheating is also easier. As a rule, braze welding operations can be done with only local preheating—that is, preheating only that portion of the part to be braze welded. In many cases, this makes it possible to repair broken castings and other parts in place, thus saving the time and expense of disassembling and reassembling.

Braze welding is very useful for repairing cast iron and steel. This process also is used on brass and copper. Braze welding is widely used in the repair of gray iron castings. Not only is it used for repairing broken castings, but also in the repair of parts, such as gear teeth. Pistons, guides, and other sliding surfaces on pumps, engines, and machinery parts are usually hard faced but may be repaired and rebuilt by braze welding.

Braze welding should not be used for the repair or rebuilding of castings where the difference in color between the filler metal and cast iron would be objectionable. Nor should braze welding be used to join parts which will be subjected to temperatures higher than 650°F. Braze welding should not be used to repair working parts or containers used in chemical processes.

The best filler metal for braze welding is a naval brass, which has a copper-zinc ratio of about 60 percent copper and 40 percent zinc. This ratio produces the best combination of high tensile strength and ductility. The filler metal possesses considerable strength when hot and has the narrowest freezing range (solidifies quicker) of the entire usable copper-zinc combinations. This is an additional advantage, as a quick-freezing filler metal has much better weldability than one which remains mushy over a wide temperature range.

Most of the commercial braze welding filler metals are modifications of this 60/40 copper-zinc alloy, with small additions of tin, iron, nickel, manganese, silicon, and other elements.

Strong braze welded joints depend on proper preparation, the use of the correct technique, the strength of the filler metal, and coalescence of the filler metal and the base metal. The strength of a braze welded joint does not depend upon a thin film of filler metal between close fitting surfaces as is the case in a soldered or a brazed joint. Heavy deposits of silver-base filler metals have low strength values, but heavy deposits of copper-base braze welding filler metals frequently attain strength comparable to welded joints.

Adequate preparation, which includes thorough cleaning, is essential in braze welding. Remove all foreign matter—oil, grease, oxides. The metal on the underside as well as on the top of the joint must be bright and clean. If the parts to be joined or repaired are thin (less than 1/4 inch) it is not necessary to "V" the edges—unless the metal is 3/16'' cast iron, in which case it would be best to V the edges for proper penetration. If the cross section of the base metal is 1/4 inch or larger, the edges must be beveled to about a 60° included angle. In beveling remove as little metal as possible depending upon the thickness.

The edges can be beveled by grinding, by sanding with a portable sander, or by filing and wirebrushing. Do not grind cast iron or malleable iron for braze welding, because the grinding will tend to smear the graphite particles over the surface in such a way as to interfere with the tinning. Remember, too, that it is not good practice to bevel the welding V with a torch, unless the oxides and free graphite are removed from the surface before braze welding. If you should have a job involving cast iron or malleable iron and machining, grinding, or torch-beveleing should become necessary, then finish the surfaces by filing and wirebrushing. You can also remove the graphite smear by heating the parts to a dull red with an oxidizing flame. The metal for at least 1/2 inch back from the top edge of the V should be thoroughly cleaned to permit easy tinning. Without tinning, a satisfactory braze-welded joint is impossible.

The parts must be placed in proper alignment and kept in their relative positions during the brazing process. You can best accomplish this by using clamps and by tack welding.

In braze welding, a casting must be heated along the line of the weld. This sets up strains, due to expansion and contraction, unless the casting is properly preheated. In a small casting, up to about a hundred pounds, the heat from the torch is sufficient to preheat the entire casting. Larger castings should, however, be thoroughly preheated to approximately 900°F and not over 1000°F. Besides providing for the relief of stresses, preheating speeds up the braze welding operation and requires less oxygen and acetylene.

Preheating can be done with a torch, with an improvised firebrick furnace covered with asbestos paper, or with an oil or gas burner. At times, castings attached to a machine may be welded in place. Often such castings can be preheated by playing the flame along the line of the weld and protecting the surrounding surfaces with asbestos paper. Large castings should be postheated to relieve stresses; the amount of postheat depends upon the thickness of the casting.

The use of a flux is essential in braze welding with an oxyacetylene flame. It is needed for two reasons: (1) to remove oxide that forms ahead of the welding zone, due to the oxygen in the air; and (2) to dissolve the oxides formed in the braze welding operation. Use plenty of flux in the tinning operation, but in filling the V use flux sparingly. When you see that additional flux is required, add it carefully. The puddle should not be made mirror clear but left slightly clouded with oxide. Where the braze welding is rapid, it is best to coat the rods entirely with flux. If the operation is slow, as with heavy castings, you can deip the hot end of the welding rod into the flux and add to the puddle as required.

For braze welding a slightly oxidizing flame is used. Periodic checks should be made to be sure that this adjustment is maintained. A slightly oxidizing flame helps to secure a better bond between the filler metal and the base metal. It also assists in keeping a slight film of oxide over the puddle. This film of oxide serves to protect the weld metal from the oxygen in the air.

After the parts have been properly prepared—cleaned, aligned, and preheated if necessary—the parts are then tack welded together. The metal is then heated with a torch at the point where the braze weld is to start. Play the torch flame over the part to be heated, using a circular motion. As the base metal gets hot, test its temperature with a drop of metal from the welding rod. When the base metal is at the right temperature, molten filler metal spreads evenly over the surface. This produces a tinning coat on the base metal.

You can tin the base metal in braze welding only when the conditions are just right for it. If the base metal is too cold, the filler metal will not run out and spread over the heated surface as it should. If the base metal is too hot, the filler metal will form little balls like drops of water on a hot stove. If the temperature of the base metal is right and the tinning is done properly, the molten filler metal will spread over the surface like water spreading over a clean, moist surface.

The most important phase of the braze welding procedure is tinning, which is the process of depositing the thin free-flowing film of filler metal that provides the intimacy of contact necessary for coalescence between the base metal and the filler metal. When the immediate area

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under the torch flame is tinned, additional metal is added as necessary to fill the V. Tinning must, at all times, continuously precede filling the joint.

As the tinning action is in progress, continue to feed the brazing filler metal into the molten puddle to build the weld up to the desired size. The puddle should be small in size, but increased as it is moved forward, until it completely fills the V and a full-sized braze weld is made. Be sure that the tinning action takes place continuously, just ahead of the puddle. Good braze welding combines into one continuous operation the tinning action and the building up of the braze weld to the desired size.

The inner flame cone is kept from 1/8 to 1/4 inch away from the surface of the metal. Usually the flame is pointed ahead of the completed part of the weld at an angle of about 45°, with the puddle under and slightly behind the flame. You vary the angle, however, when brazing in flat, overhead, and vertical positions. Also the angle will vary with the size of the puddle being carried, the nature of the surface, and the speed of welding. Although brazing can be done in any position, the flat position should be utilized if possible.

Bright spots on the metal in the puddle mean that oxides and impurities are present and should be worked out with the torch flame or with the flux. Don't use too much flux, though, as this is wasteful and prevents making the best joint. Use just enough flux to get a good tinning action between the filler metal and the base metal. The proper rate of braze welding is controlled by the rate of tinning; never allow the puddle to get ahead of the tinning action.

If it is necessary to deposit filler metal in layers, as when braze welding heavy materials, the tinning of the base metal is particularly important. If the tinning is good and fusion between the layers is complete, a strong braze weld is assured.

After you have finished the braze welding operation, play the torch over the weld and on either side of the weld for several inches. The size of the weld and the size of the casting determine the size of the area that should be heated. Continue to heat until all sections of the part have been brought to even heat. If the repaired part is small, bury it in dry slaked lime. If it is large, cover it with asbestos cloth. In either case, allow it to cool slowly. The parts should be protected from drafts and cold air, which would cause them to cool unevenly. Never subject a braze welded joint to stress until it has completely cooled.

HARD-FACING

Hard-facing is a process in which a layer of some special ferrous or nonferrous alloy is applied to the surface of new or old parts to increase their resistance to abrasion, impact, corrosion, or erosion, or to obtain other properties. Hard-facing is also used to build up undersized parts. You may hear the process of hard-facing referred to as hard-surfacing, resurfacing, surfacing, or wear facing.

Among your most important duties will be those where you will build up and hard-face various types of worn metal parts of construction equipment. These parts include the cutting edge of scraper or dozer blades, sprocket gears, and the teeth of shovels or clam shells. You may even hard-surface a new blade or shovel teeth before the part is put into service for the first time. There are a number of different methods of hard-facing. In this discussion, however, we are mainly interested in the oxyacetylene process of hard-facing.

Hard-facing provides a means of maintaining sharp cutting edges. It will often reduce wear between metal parts. Hard-facing also reduces maintenance costs and down-time. These and other advantages of hard-facing add up to increased service life and higher efficiency of equipment.

Hard-facing with the oxyacetylene flame is in many respects similar to braze welding. Frequently, copper-base alloys are used in surfacing, but in many instances special surfacing alloys are required. In either event, hard-facing is a process in which a layer of metal of one composition is caused to coalesce to the surface of a metal of another composition.

Before hard-facing a part, be sure that hard-facing is needed. If abrasion is present, it probably will be desirable to hard-face the part. When failure of a part is due to impact, heat, or corrosion, hard-facing seldom will be practicable. When a part is subject to impact, build it up with manganese steel electrodes and it will work harden on the surface. Underneath the work hardened surface, the manganese will remain ductile and will be able to withstand impact. If a part is subject to heat or corrosion, it can be built up with an electrode with a high chrome content to enable it to withstand this type of wear.

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The process of hard-surfacing is readily applicable to all low-carbon alloy and stainless steels as well as to monel and cast iron. It is not intended for aluminum, copper, brass, or bronze. The melting point of these materials prohibits the use of the hard-surfacing process. It is possible to increase the hardness of aluminum by applying a zinc aluminum solder to the surface. Copper, brass and bronze can be improved in their wear ability by the overlay of work hardening bronze. Tool steels, both carbon and alloy, can be surface-hardened, but they offer difficulties due to the frequent development of shrinkage and strain cracks. If these materials are surfaced, they should be in an annealed and not a hardened condition. If necessary, heat treating and hardening can be performed after the surfacing operation. Quench the part in oil—not water.

MATERIALS

A surfacing operaion using a copper-base alloy filler metal produces a relatively soft surface. Work hardening bronzes are soft when applied and give excellent resistance against frictional wear. Other types of alloys are available which produce a surface that is corrosion- and wear-resistant at relatively high temperatures. Many hard-facing materials are produced by different manufacturers. Be sure that the filler alloys you select for a particular surfacing job meet Navy specifications.

Two types of hard-surfacing materials in general use in the Navy are iron-base alloys and tungsten carbide.

IRON-BASE ALLOYS contain nickel, chromium, manganese, carbon, and other hardening elements. These alloys are used for a number of applications requiring varying degrees of hardness. The Steelworker will frequently work with iron-base alloys when he builds up and resurfaces parts of construction equipment.

TUNGSTEN-CARBIDE is used for building up wear-resistant surfaces on steel parts. Tungsten-carbide is one of the hardest substances known to man; diamonds are one of the few substances which are harder. Tungsten-carbide may be applied in the form of inserts or of composite rod. Inserts are not melted, but are welded or brazed to the base metal. The rod is applied with the same surfacing technique as that used for oxyacetylene welding; a slightly carburizing flame adjustment is necessary.

HARD-FACING OPERATIONS

Proper preparation of the metal surfaces is an important part of hard-facing operations. Make sure that scale, rust, and foreign matter are removed from the metal survaces. (On construction equipment such as teeth, it will not make much difference if the metal is a little dirty.) The metal surfaces can be cleaned by grinding, machining, or chipping. The edges of grooves, corners, or recesses should be well rounded to prevent overheating of the base metal, and to provide a good cushion for the hard-facing material.

Hard-facing material is usually applied so that it forms a thin layer over the base metal. The thickness of the deposit is usually from 1/16 to 1/8 inch, is seldom over 1/4 inch, and is generally deposited in a single pass. Where wear is extensive it may be necessary to use buildup rod prior to hard-facing. If you are in doubt whether to use a buildup rod, check with your leading petty officer.

In general, the torch manipulation employed and the hard-facing procedure itself are similar to brazing techniques. However, higher temperatures (about 2200° F) are necessary for hard-surfacing, and tips one size larger than normal are used. A small area should be heated with a sweeping torch movement until the surface of the base metal takes on a SWEATING or wetted appearance. When the surface of the base metal is in this condition, the end of the surfacing alloy is brought into the flame and allowed to melt. Do not stir or puddle the alloy; let it flow. If the surface area has been properly sweated, the alloy will flow freely over the surface of the base metal.

Being able to recognize a sweated surface is essential for surfacing. This sweating occurs when the temperature of steel is raised to a white heat with a carburizing flame. An extremely thin layer of the base metal is carburized. The carburized layer has a lower melting point than the rest of the base metal. As a result it becomes a liquid while the underlying metal remains a solid. This liquid film provides the medium for flowing the filler metal over the surface of the base metal. The liquid film is similar to and serves the same purpose as a tinned surface in soldering and braze welding. The carburized layer is approximately 0.001 inch thick.

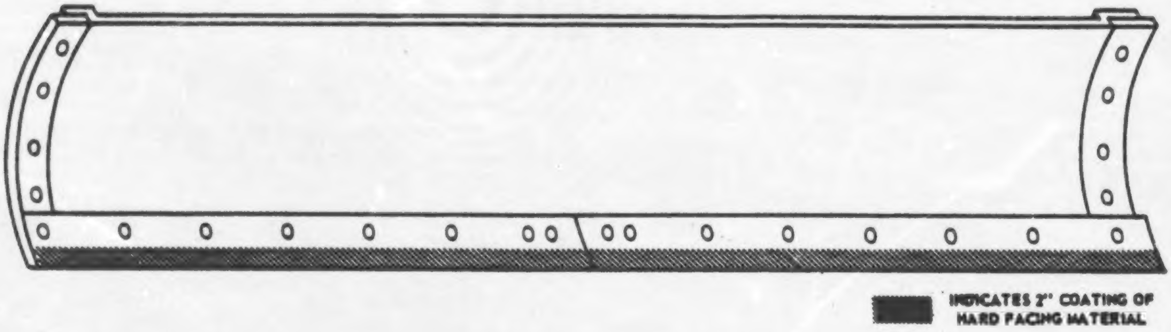

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Figure 10-11.—Grader blade with hard-facing material applied to cutting edge.

When heating steel with a carburizing flame, the steel first becomes red and, as heating continues, the color becomes lighter and lighter until a bright whiteness is attained. At this point, a thin film of liquid, carburized metal appears on the surface. Surfacing alloy added at this time flows over the sweated surface and absorbs the film of carburized metal. This surface condition is not difficult to recognize, but you should make several practice passes before you try hard-facing for the first time.

When using an oxyacetyle torch for surfacing with chromium-cobalt, the torch flame should have an excess acetylene feather about three times as long as the inner cone. Unless the excess acetylene flame is used, the proper base metal surface condition cannot be developed, and the surfacing alloy will not spread over the surface of the part.

Figure 10-11 illustrates a grader blade with a deposit of hard-facing material applied along the cutting edge. A grader blade is usually hard-faced by the electric arc process; but, if the electric arc process is not available you may use the oxyacetylene torch. In hard-facing a grader blade, see that the metal surface is cleaned thoroughly. Position the blade in a suitable prebending jig or bolt two blades back-to-back. Light off the oxyacetylene torch and preheat the metal to 500° to 600° F. As the next step, adjust the oxyacetylene torch to give a slight excess acetylene flame; then apply the filler metal with a weaving motion or in stringer beads. The skip weld method should be used. You should also start at the center and work toward each end. Continue the hard-facing operation until you have a 2-inch wide deposit along the edge of the blade.

SPOT HEATING

The process of SPOT HEATING with an oxyacetylene torch is frequently used for straightening bent structures and for shortening metal shapes. You will find spot heating fairly easy as long as you use the proper amount of heat in the right place, since metal expands when heated and contracts when cooled. A 12-inch bar of steel, for instance, when heated to forging temperature, expands about 1/8-inch per foot; then, when it has cooled to room temperature, the bar contracts to the original size.

The principle of straightening by spot heating is based on controlled expansion and normal contraction of metal during heating and cooling. If a 12-inch bar is secured in a die so that it cannot increase in length when heat is applied, the metal will upset. When the bar contracts on cooling, the overall length of the bar will be less than 12 inches—about 1/8-inch shorter as there is nothing to prevent contraction.

Figure 10-12 illustrates what happens if heat is applied in one spot when a shape is in a fixed position. It cannot go anywhere by expansion, but the side which was heated shrinks with cooling. The result is illustrated by the warped section to the right in the figure.

To straighten a warped bar, you should apply heat to the longer edge, as illustrated in figure 10-13.

CONTROL OF HEAT

The secret—if there be any—lies in the control of heat. When heat is applied at one spot, it rapidly flows to other parts of the bar by conduction. This heat flowing has to be controlled

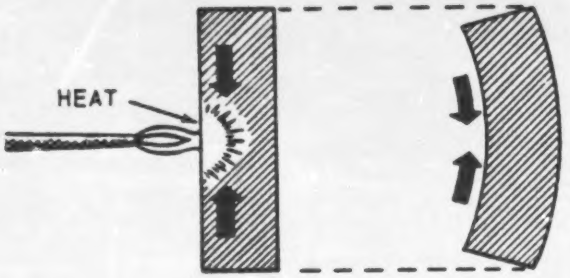

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Figure 10-12.—One edge shortened.

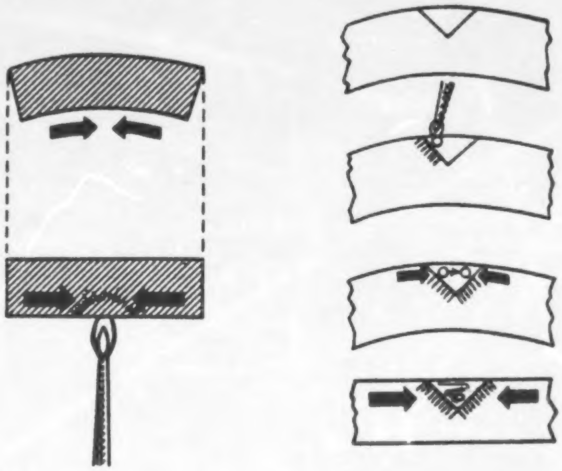

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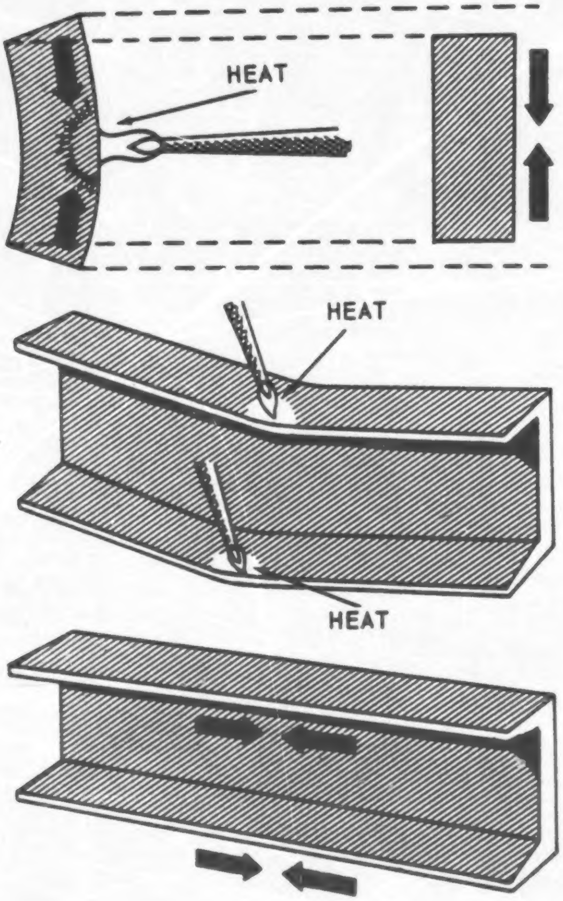
Figure 10-14.—How to control the heat.



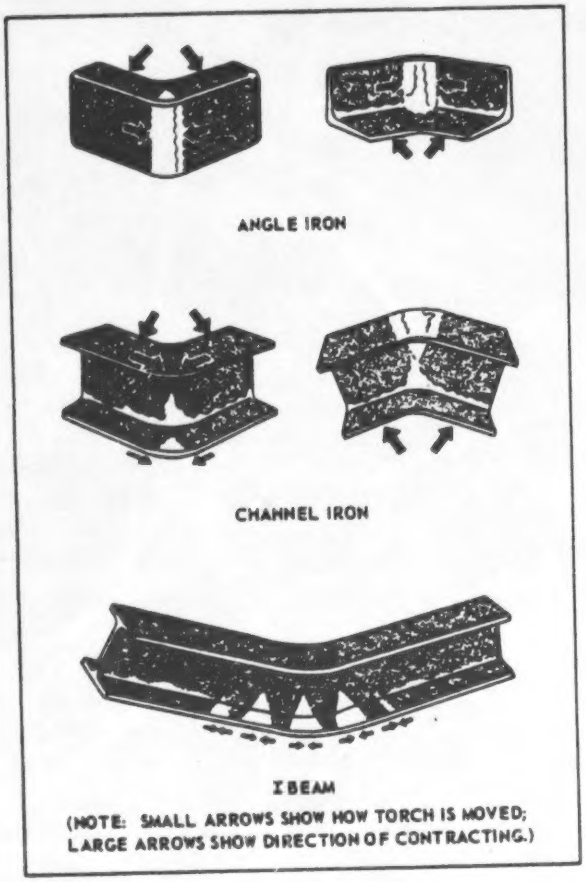
127.23
Figure 10-13.—Straightening a bent channel.

so that the metal will upset just where you want it. You cannot completely control "heat-flow," but with proper manipulation of the heating torch you can keep the heat flowing to a minimum. This takes practice, however.

Figure 10-14 shows one good way to control heat. First mark with soapstone the area to be heated. Usually this will be in the shape of a V or triangle becuase more heat is wanted at the outer part of the bend and less toward the center. When using an oxyacetylene torch, select a fairly large welding tip and hold the flame steady at one point until the metal reaches a light cherry red color. Start at the apex of the triangle or at the outer edge as shown in figure 10-14. When the small area beneath the tip has reached the proper temperature, slowly move the tip to one side so that the circular area of heated metal moves with it.

TORCH MOTION

In spot heating, the tip must be held steady, somewhat as it is in flame cutting. Do not use the weaving motion that you would use in welding. Watch the work closely and keep the hot spot moving properly. Otherwise, there will be no upsetting and the metal may be burned. Under no circumstances should the metal be heated to the melting point. Keep the metal on the inside of the bend cool by the use of water, ice, wet rags, or a water spray. Continue the heating until


ANGLE IRON
CHANNEL IRON
I BEAM
(NOTE: SMALL ARROWS SHOW HOW TORCH IS MOVED; LARGE ARROWS SHOW DIRECTION OF CONTRACTING.)

127.25
Figure 10-15.—Examples of straightening by spot heating.

the little circle of hot metal has covered all the area within the triangle; then allow the member to cool. With this procedure you will get an appreciable bend. If the first bend is not sufficient, repeat the operation. If the first attempt bends the piece too much, reverse it slightly by applying heat to the opposite side.

It is better to apply a little heat several times than too much heat all at once. Long bends are best straightened by heating several times at intervals along the length of the bend. Remember that heating must be carried out on both sides of the flange or centerline of the member, particularly if the metal is thick. This is to provide even heating and subsequent even contraction.

Figure 10-15 shows how several different members can be straightened by spot heating. Do not try this method on a structural member until you have practiced on scrap material and know what you are doing. If the section is a heat-treated or tool-steel part, it will be better to leave it alone until the entire unit can be taken down and repaired with usual shop procedures.